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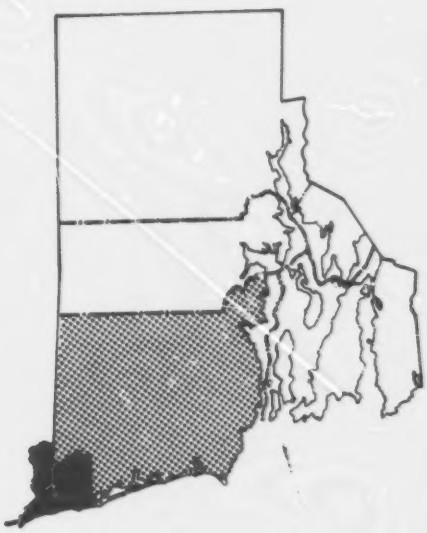
FLOOD INSURANCE STUDY

ORIGINAL

TOWN OF WESTERLY, RHODE ISLAND
WASHINGTON COUNTY



FEBRUARY 5, 1986

Federal Emergency Management Agency

COMMUNITY NUMBER - 445410

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TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
	1.1 Purpose of Study	1
	1.2 Authority and Acknowledgements	1
	1.3 Coordination	1
2.0	AREA STUDIED	2
	2.1 Scope of Study	2
	2.2 Community Description	4
	2.3 Principal Flood Problems	5
	2.4 Flood Protection Measures	7
3.0	ENGINEERING METHODS	7
	3.1 Hydrologic Analyses	8
	3.2 Hydraulic Analyses	12
4.0	FLOOD PLAIN MANAGEMENT APPLICATIONS	16
	4.1 Flood Boundaries	16
	4.2 Floodways	17
5.0	INSURANCE APPLICATION	21
	5.1 Reach Determinations	21
	5.2 Flood Hazard Factors	23
	5.3 Flood Insurance Zones	24
	5.4 Flood Insurance Rate Map Description	25

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TABLE OF CONTENTS - continued

	Page
6.0 OTHER STUDIES	25
7.0 LOCATION OF DATA	26
8.0 BIBLIOGRAPHY AND REFERENCES	26

FIGURES

Figure 1 - Vicinity Map	3
Figure 2 - Flood Photograph - Damage on Misquamicut Beach in January 1978	6
Figure 3 - Transect Location Map	15
Figure 4 - Floodway Schematic	20

TABLES

Table 1 - Summary of Discharges	10
Table 2 - Summary of Stillwater Elevations	11
Table 3 - Floodway Data	18 - 19
Table 4A - Flood Insurance Zone Data	22
Table 4B - Flood Insurance Zone Data	23

EXHIBITS

Exhibit 1 - Flood Profiles	
Pawcatuck River	Panels 01P - 04P
Mastuxet Brook	Panels 05P - 06P
Exhibit 2 - Coastal Profiles	
Transects 1-14	Panels 01C - 14C
Exhibit 3 - Flood Boundary and Floodway Map Index	
Flood Boundary and Floodway Map	

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PUBLISHED SEPARATELY:

Flood Insurance Rate Map Index
Flood Insurance Rate Map

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FLOOD INSURANCE STUDY
TOWN OF WESTERLY, RHODE ISLAND

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study investigates the existence and severity of flood hazards in the Town of Westerly, Washington County, Rhode Island, and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood risk data for various areas of the community that will be used to establish actuarial flood insurance rates and assist the community in their efforts to promote sound flood plain management. Minimum flood plain management requirements for participation in the National Flood Insurance Program are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some states or communities, flood plain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the state (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgments

The sources of authority for this Flood Insurance Study are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The hydrologic and hydraulic analyses in this study represent a revision of the original analyses performed by the U. S. Army Corps of Engineers (COE) for the Federal Emergency Management Agency (FEMA), under Inter-Agency Agreement No. IAA-H-8-71. The updated version was prepared by Stone & Webster Engineering Corporation for FEMA, under Contract No. EMW-C-0405. This work was completed in October 1981.

1.3 Coordination

On September 7, 1979, an initial Consultation and Coordination Officer's (CCO) meeting was held with representatives of FEMA, the Town of Westerly, and Stone & Webster Engineering Corporation (the study contractor). At this meeting, areas to be studied in detail and general background information on flooding and potential development were obtained from the town engineer. Upon initiation of the study, the Westerly Sun and the Providence Journal ran an announcement of intent to perform the Flood Insurance Study.

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During the course of the study, general community information as well as information on past flooding in Westerly was requested (and obtained when available) from town officials, the Westerly Sun, the Greater Westerly-Pawcatuck Chamber of Commerce, the Rhode Island Department of Economic Development, the University of Rhode Island Coastal Resource Management Center, the Rhode Island Department of Environmental Management, and the Soil Conservation Service (SCS). The U. S. Geological Survey (USGS) was contacted for flows from the Pawcatuck River and for methods of flow determination for Mastuxet Brook. The COE and FEMA were contacted for data concerning coastal flood elevations. A street map of the town was obtained from the James E. Sewall Company. In only one instance was a request for information refused. The Bradford Dyeing Association refused to provide available information concerning the dam that it controls on the Pawcatuck River. The association also refused to allow a survey crew to enter the area of the dam site. Data for the dam, required for the hydraulic analysis, were conservatively estimated from the photogrammetrically produced topographic maps drawn for this Flood Insurance Study and from a field visit view of the dam as seen from the upstream highway bridge. Coordination with interested parties was maintained throughout the course of the study.

On November 25, 1981, the preliminary results of the study were presented to the town by FEMA and the study contractor at an intermediate CCO meeting. On February 26, 1985, the results of the study were reviewed at a final CCO meeting attended by representatives of FEMA, the town, and the study contractor.

2.0 AREA STUDIED

2.1 Scope of Study

This Flood Insurance Study covers the incorporated area of the Town of Westerly, Washington County, Rhode Island. The area of study is shown on the Vicinity Map (Figure 1).

Riverine flooding on the Pawcatuck River and Masuxet Brook were studied by detailed methods. The Pawcatuck River was studied from a point approximately 2,000 feet south of State Route 78 to the eastern corporate limits. Mastuxet Brook was studied from the downstream side of Watch Hill Road (State Route 1A) to the downstream side of Airport Road. Tidal flooding including its wave action from Block Island Sound was also studied by detailed methods. The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction through October 1986.

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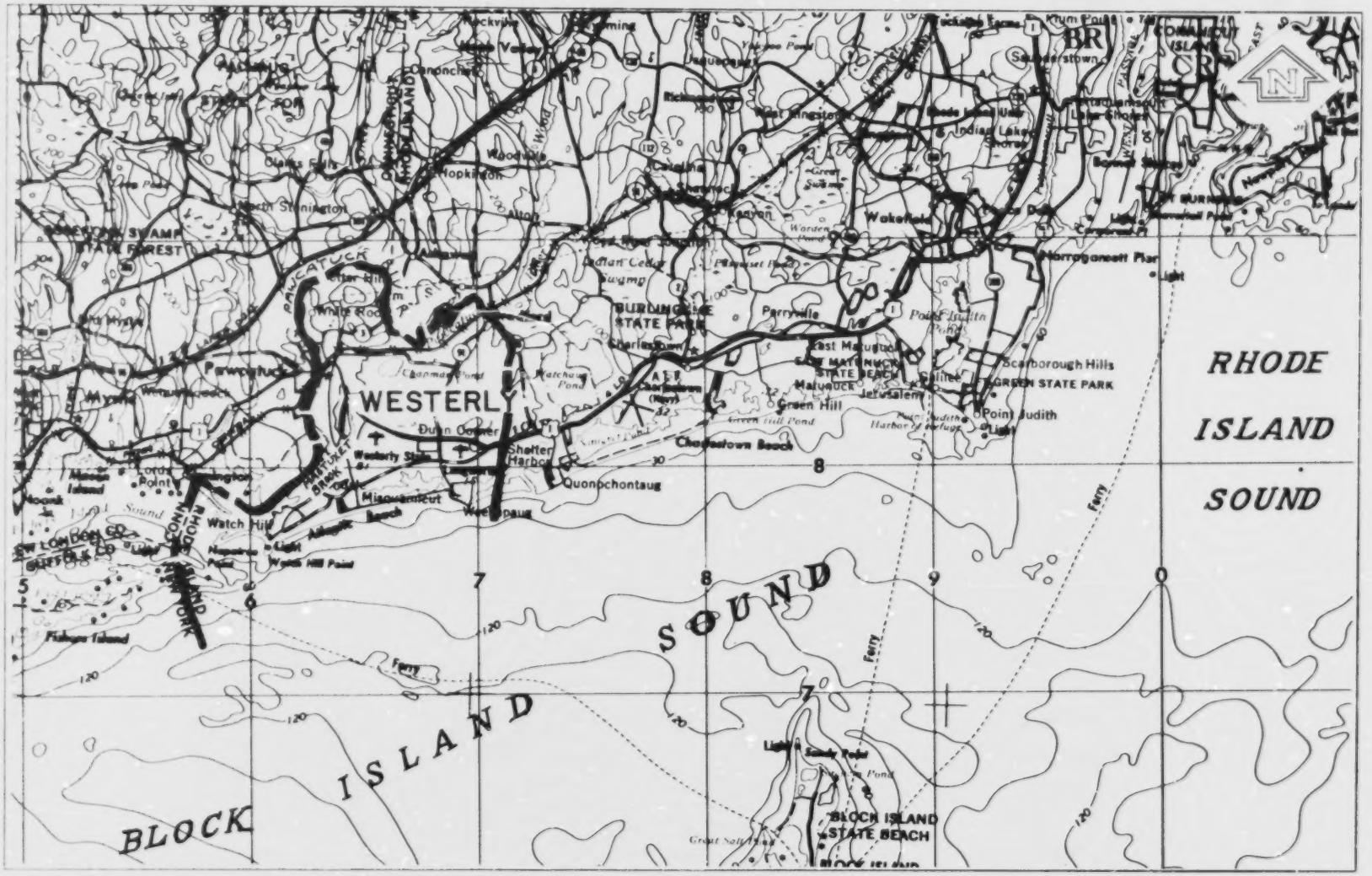

FIGURE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, R.I.

(WASHINGTON CO.)

APPROXIMATE SCALE

4 0 4 8 12 MILES

VICINITY MAP

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Originally, Mastuxet Brook was to be studied to the upstream side of U. S. Route 1; however, during the reconnaissance effort, it was discovered that the large swampy area north of U. S. Route 1 does not drain to Mastuxet Brook. Thus, the drainage area for the portion of the brook above Airport Road is less than 1 square mile and the detailed study analysis was stopped at this point.

Areas studied by approximate methods include a portion of Mastuxet Brook, Aguntaug Brook, McGowan Brook, Chapman Pond (including the surrounding swamp), and Dr. Lewis Pond. Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon by, FEMA and the Town of Westerly.

2.2 Community Description

The Town of Westerly is located in the southwestern portion of Washington County in southwestern Rhode Island. Westerly is approximately 18 miles east of New London, Connecticut, and 42 miles southwest of Providence, Rhode Island. It is bordered by the Town of Charlestown, Rhode Isand, to the east; Block Island Sound to the south; the Town of Stonington, Connecticut, to the west; and the Town of North Stonington, Connecticut, and the Town of Hopkinton, Rhode Island, to the north.

Westerly is a manufacturing and residential community that attracts both a permanent and seasonal population. The population of Westerly was 18,507 in 1980, a 7 percent increase from 17,248 in 1970 (Reference 1). The population density rose during this period from 581 persons per square mile to 623 persons per square mile (References 2 and 3).

The coastal area of Westerly is fronted by barrier beaches that protect a relatively flat to mildly sloping coastline. In many areas, recreational use of the shoreline has kept the barrier beaches from fully recovering from past storms. Development along the beaches has been light after the large hurricanes of 1938 and 1954, except in the Atlantic Beach area. Homes and businesses built in this area have replaced structures destroyed by the large storms (Reference 4).

The Pawcatuck River basin drains the northern and western portions of the Town of Westerly. The town is located at the downstream end of the drainage basin which has a total area of 303 square miles. The watershed is irregular in shape with the longest dimension being 22 miles. The maximum elevation is slightly over 600 feet in the northern portion of the basin; however, the average elevation is less than 200 feet. Low rounded hills rise above very wide valleys where the major relief features are composed of glacial deposits. Much of the basin consists of wide, flat, swampy valleys, making the average slope of the river quite

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low. Development in the basin is limited, and many large areas have been set aside by the State of Rhode Island as state forests or parks. A large part of the Great Swamp in South Kingstown, Rhode Island, is designated as a wildlife reservation. A 17 mile long reach of the Pawcatuck River borders Westerly and has a drainage area of approximately 100 square miles. Approximately 5 miles of the river upstream of the confluence at Little Narragansett Bay are tidally influenced (Reference 5).

The climate of the town is variable. The average annual precipitation is approximately 43 inches. Mean temperatures for January and July are approximately 30 degrees Fahrenheit (°F) and 70°F, respectively, with an average annual temperature of approximately 50°F (Reference 2).

2.3 Principal Flood Problems

Flooding in Westerly is generally limited to the coastal lowlands along Block Island Sound and the lower elevations along the Pawcatuck River. The most severe coastal flooding occurs during hurricanes, which are tropical in nature and are characterized by low barometric pressures, wind speeds greater than or equal to 75 miles per hour, torrential rain, tremendous waves, and tidal flooding. Severe coastal flooding resulted from the hurricanes of September 1938 and August 1954. Both of these storms had a severe effect on portions of the coastline of Westerly east of Maschaug Pond. Along the Napatree Beach and Watch Hill Point areas, the recurrence intervals for the 1938 and 1954 hurricanes were estimated to be approximately 75 years and 55 years, respectively; however, east of Maschaug Pond the recurrence intervals for the 1938 and 1954 hurricanes were estimated to be approximately 100 years and 85 years, respectively.

The 1938 and 1954 hurricanes caused extensive damage to the barrier beaches along the coastine of Westerly. The 1938 hurricane destroyed all structures that had been built on the Napatree Point barrier beach, on the lower elevations of the Winnapaug Pond barrier, and probably on all other low lying areas along the coast. The 1954 hurricane, Hurricane Carol, also washed away many shorefront homes and damaged the dunes that protect the inland areas along the coast. The natural processes that tend to rebuild the barrier beaches have been hampered by increased use of the beaches for recreational purposes, leaving some of the more inland development open to wave attack from hurricanes (Reference 4). Coastal storms of lesser magnitude have caused damage in the recent past by eroding the beach in many locations. Figure 2 is a photograph of damage at Misquamicut Beach following a coastal storm in January 1978.

Riverine flooding has not been a major problem to date on the Pawcatuck River. The vast amount of swampland within the basin has made for very

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Figure 2 - Damage to a food establishment on Misquamicut Beach after a storm in January 1978.

slow flood formation with only minor peak floods (Reference 5). USGS stream flow records collected in the vicinity indicate that annual peak flow can occur during any season of the year, but occurs most frequently from December through April. Runoff from spring rains, sometimes accompanied by snow melt, usually causes the highest peak flows to occur during March or April; otherwise, they occur during September or October due to runoff from tropical storms (Reference 6). The March 1968 flood, which was the most severe flood in the past 50 years, produced a peak discharge of 4,470 cubic feet per second (cfs) on the Pawcatuck River at the Westerly gage. This flood had an estimated recurrence interval of 30 years. More recently, in January 1978 and January 1979, floods produced peak discharges at the Westerly gage of 4,110 cfs and 4,010 cfs, respectively. The estimated recurrence interval for these storms is 20 years (Reference 7).

2.4 Flood Protection Measures

Existing flood protection along most of the coast of Westerly is limited to the natural protection offered by the barrier beaches themselves, a stretch of sand fill placed by the State of Rhode Island at Misquamicut Beach in 1959 and 1960, and a few seawalls. A multiple purpose project combining tidal flood protection and beach erosion control for the Misquamicut-Winnapaug Pond area was proposed by the COE in 1965; however, there are no plans to carry out the project as of this date (Reference 5).

Westerly has effective ordinances protecting its barrier beaches. Except for Atlantic Beach, the barrier beaches are zoned as flood prone residential areas, and development is stringently controlled. No building is permitted on dunes, and the owners of homes built behind dunes are required to protect them by building boardwalks to the beaches and by erecting snow fences (Reference 4).

The dam on the Pawcatuck River controlled by the Bradford Dyeing Association does provide some control of flood flows on the Pawcatuck River; however, there is little available data for this dam. Data for this dam were estimated for the purposes of this study.

There are no other flood control structures affecting streamflow in Westerly. Most of the dams on the Pawcatuck River are old mill dams that are not operating. Neither these dams, nor the dams for the few mills still operating, are regulated.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard

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data required for this study. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for flood plain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10, 2, 1, and 0.2 percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1 percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge-frequency and peak elevation-frequency relationships for the flooding sources studied in detail affecting the community.

Peak discharges for the Pawcatuck River were estimated on the basis of peak flood discharge information from two gaging stations on the river. One gaging station is located at Wood River Junction in Hopkinton. This gage has been in operation since October 1940. The other gaging station is located at Westerly and has been in operation since November 1940. The most recent peak flood discharge frequency distributions for the two gages were obtained from the USGS (Reference 7).

The most downstream section of the Pawcatuck River forms the border between Stonington, Conncecticut, and Westerly, Rhode Island. The nontidal portion of this section of the river extends from a point downstream of the State Route 78 bridge to the confluence with the Shunock River. This section was recently studied in detail for the Flood Insurance Study for the Town of Stonington (Reference 8). In that study, the Westerly gaging station flow frequency distribution based on peak flood discharges prior to 1978 was used directly to determine the peak flood discharges for the 10-, 50-, 100-, and 500-year recurrence intervals. The direct application of flood frequency analyses for the Westerly gaging station to the nontidal portion of the Pawcatuck River downstream of the confluence of the Shunock River was found to be reasonable. Because the peak discharges presented in the Stonington study did not differ greatly from the discharges obtained from the 1980 frequency distribution, the discharges from the Stonington study were used for this Flood Insurance Study for Westerly.

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For all locations on the Pawcatuck River upstream of the confluence with the Shunock River, peak discharges were estimated on the basis of a drainage area proration of discharges from the flood frequency distributions for both the Westerly and the Wood River Junction gaging stations. The 10-year return period at each of these two gages was plotted against the drainage area for the corresponding gage on log-log graph paper. A line was then drawn between the two plotted points, and the slope, n, of this line was calculated. This same procedure was also carried out for the 50-, 100-, and 500-year recurrence intervals to yield a total of four plotted lines, each having a unique slope. Slopes ranged from 1.05 for the 500-year recurrence interval flood to 1.09 for the 10-year recurrence interval flood. Each line is of the form:

$$Q_1/Q_2 = [A_1/A_2]^n$$

where Q_1 and A_1 are the discharge and drainage area, respectively, at the Wood River Junction gage; Q_2 and A_2 are the discharge and drainage area, respectively, at another location; and the exponent, n, is the slope as defined above (Reference 9).

The series of A_2 values (the drainage areas at the locations along the Pawcatuck River) were determined by planimetering USGS quadrangle sheets covering the drainage basins. These drainage areas were then used in the equation described to determine the series of discharges at these selected locations.

For the stretch of the Pawcatuck River above the confluence with Ashaway River, the drainage area proration described above was recently performed for the Flood Insurance Study for the Town of Hopkinton using frequency distributions based on peak flood discharges prior to 1979 for the two gages on the Pawcatuck River (Reference 6). The discharges obtained for this study (based on 1980 frequency distributions) did not differ greatly from those presented in the Hopkinton study; therefore, the discharges from the Hopkinton study were used for this study.

No gage exists on Mastuxet Brook; therefore, peak flood discharges for the brook were computed using an extension of a regional method of peak flow prediction applicable to New England (Reference 10). The regional method was extended by estimating the Mean Annual Flow (MAF) for gaged streams in the Westerly area for which the drainage area above the gage was less than 10 square miles. A regression line was drawn through the plot of the MAF values for 31 gages (each in operation for at least 5 years). The MAF for each of the two drainage areas of interest was taken from this line and used, along with the appropriate curves from the Water-Supply Paper 1671 publication, to determine the discharges for the recurrence intervals of interest (Reference 10).

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A summary of drainage area-peak discharge relationships for the streams studied by detailed methods is shown in Table 1, "Summary of Discharges."

TABLE 1 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-YEAR	50-YEAR	100-YEAR	500-YEAR
PAWCATUCK RIVER					
Above USGS Gage No. 01118500 below Stillman Avenue	295.0	3,400	4,900	5,700	7,900
Above confluence with Shunock River	279.2	3,300	4,600	5,200	6,850
Above confluence with Ashaway River	244.0	2,700	3,750	4,300	5,650
Above confluence with Tomaquag Brook	212.4	2,450	3,400	3,900	5,100
MASTUXET BROOK					
At State Route 1A	1.5	90	170	230	370

Tidal elevation-frequency relationships for Block Island Sound are based on a combination of storm-surge frequency analyses performed by the COE and other independent contractors' analyses (References 11, 12, and 13). A flood frequency analysis done at the tide gage in New London, Connecticut, presented elevations for the 10-, 50-, 100-, and 500-year recurrence interval storms. At the eastern end of Block Island Sound, elevations were presented for the same recurrence interval storms at Narragansett Pier in Rhode Island (Reference 13). These values were computed by developing a stage-correlation curve to relate flooding at Narragansett Pier to flooding at the Newport tide gage based on several high-water marks at Narragansett Pier. A Pearson Type III analysis was then run on the extended historical record at Narragansett Pier to establish the stage-frequency relationship. The analyses at both New London and at Narragansett Pier were performed specifically for the National Flood Insurance Program. Tidal flood elevations for shoreline locations between New London and Narragansett Pier are based on interpolation between these two points (References 12 and 13). Data presented by the COE were used as a guideline (Reference 11).

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For the tidal section of the Pawcatuck River, flood elevations are presented in the current Flood Insurance Study for the Town of Stonington, Connecticut (Reference 8). The 100-year recurrence interval flood elevation computed for the area of the lower Pawcatuck River by use of the analysis cited above is more than 1/2 foot lower than the 100-year elevation presented in the Stonington study; therefore, the more recently computed flood elevation values are used in this Flood Insurance Study. Where the riverine and tidal portions of the river meet, the riverine profiles were extended downstream to join the new tidal flood elevations.

The stillwater elevations for the 10-, 50-, 100-, and 500-year floods have been determined for Block Island Sound and are summarized in Table 2.

TABLE 2 - SUMMARY OF STILLWATER ELEVATIONS

FLOODING SOURCE AND LOCATION	ELEVATION (feet) 10-YEAR	50-YEAR	100-YEAR	500-YEAR
BLOCK ISLAND SOUND				
Little Narragansett Bay and tidal portion of Pawcatuck River	6.9	9.7	11.2	15.3
Napatree Beach to west end of Maschaug Pond	7.0	9.8	11.3	15.7
West end of Maschaug Pond to west end of Winnapaug Pond	7.7	10.3	11.7	16.4
West end of Winnapaug Pond to western corporate limits	7.8	10.5	11.9	16.8

The analyses reported in this study reflect the stillwater elevations due to tidal and wind setup effects. The effects of wave action were also considered in the determination of flood hazard areas. Coastal structures that are located above stillwater flood elevations can still be severely damaged by wave runup, wave-induced erosion, and wave-borne debris. The extent of wave runup past stillwater levels depends greatly on the wave conditions and local topography.

Wave heights and corresponding wave crest elevations were determined using the National Academy of Sciences (NAS) methodology (Reference 14). The wave runup was determined using the methodology developed by Stone and Webster Engineering Corporation for FEMA (Reference 15).

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3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the riverine sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals.

For Mastuxet Brook and the upper section of the Pawcatuck River not subject to tidal fluctuations, cross section data for the above water sections were obtained by ground survey, digitized from aerial photography using photogrammetric techniques, or obtained from aerial mapping (References 6, 8, and 16). Data for the below water sections were obtained by field measurement. All bridges and culverts on these streams were field surveyed to obtain elevation data and structural geometry.

Roughness coefficients (Manning's "n") used in the hydraulic analyses were selected using engineering judgment and were based on field observations of stream channel and overbank areas. For the Pawcatuck River, the channel "n" values ranged from 0.025 to 0.050, and the overbank "n" values ranged from 0.035 to 0.150. For Mastuxet Brook, coefficients of 0.040 and 0.070 were used for the channel "n" and overbank "n" values, respectively.

Locations of selected cross sections used in the hydraulic analyses are shown of the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the Flood Boundary and Floodway Map (Exhibit 3).

Except for the reach of the Pawcatuck River between the North Stonington-Hopkinton corporate limits and the State Route 3 bridge, approximately 8,800 feet upstream, water-surface elevations of floods of the selected recurrence intervals were computed using the COE HEC-2 step-backwater computer program (Reference 17). The analysis for the approximate 8,800 foot long reach downstream of the State Route 3 bridge was taken from the Flood Insurance Study for the Town of Hopkinton using the USGS E431 step-backwater computer program (References 6 and 18). Flood profiles were drawn showing computed water-surface elevations for floods of the selected recurrence intervals.

The starting water-surface elevations for the Pawcatuck River were determined by two methods. The elevations were developed by trial and error utilizing the HEC-2 slope/area method. Then, elevations were developed by a trial and error hand calculation method, utilizing Manning's equation and solving for depth. It was found that the starting water-surface elevations determined with Manning's equation compared better with historical flood elevation data; therefore, the water-surface

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elvations for the Pawcatuck River were computed using Manning's equation (Reference 8). The starting water-surface elevation for Mastuxet Brook was taken to be mean spring high tide.

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

Hydraulic analyses, considering storm characteristics and the shoreline and bathymetric characteristics of the tidal flooding source studied, were carried out to provide estimates of the elevations of floods of the selected recurrence intervals along the shoreline.

Areas of coastline subject to significant wave attack are referred to as coastal high hazard zones. The COE has established the 3-foot breaking wave as the criterion for identifying the limit of coastal high hazard zones (Reference 19). The 3-foot wave has been determined as the minimum size wave capable of causing major damage to conventional wood frame or brick veneer structures.

A wave height analysis was performed to determine wave heights and corresponding wave crest elevations for the areas inundated by the tidal flooding. A wave runup analysis was performed to determine the height and extent of runup beyond the limit of tidal inundation. The results of these analyses were combined into a wave envelope, which was constructed by extending the maximum wave runup elevation seaward to its intersection with the wave crest profile.

The methodology for analyzing wave heights and corresponding wave crest elevations was developed by the NAS (Reference 14). The NAS methodology is based on three major concepts.

First, a storm surge on the open coast is accompanied by waves. The maximum height of these waves is related to the depth of water by the following equation:

$$H_b = 0.78d$$

where H_b is the crest to trough height of the maximum or breaking wave and d is the stillwater depth. The elevation of the crest of an unimpeded wave is determined using the equation:

$$Z_w = S_* + 0.7H_* = S_* + 0.55d$$

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where Z_w is the wave crest elevation, S_* is the stillwater elevation at the site, and H_* is the wave height at the site. The 0.7 coefficient is the portion of the wave height which reaches above the stillwater elevation. H_b is the upper limit for H_*.

The second major concept is that the breaking wave height may be diminished by dissipation of energy by natural or man-made obstructions. The wave height transmitted past a given obstruction is determined by the following equation:

$$H_t = BH_i$$

where H_t is the transmitted wave height, H_i is the incident wave height, and B is a transmission coefficient ranging from 0.0 to 1.0. The coefficient is a function of the physical characteristics of the obstruction. Equations have been developed by the NAS to determine B for vegetation, buildings, natural barriers such as dunes, and man-made barriers such as breakwaters and seawalls (Reference 14).

The third concept deals with unimpeded reaches between obstructions. New wave generation can result from wind action. This added energy is related to distance and mean depth over the unimpeded reach.

The methodology for analyzing wave runup was developed by Stone and Webster Engineering Corporation (Reference 15). The wave runup computer program operates using an ensemble of deepwater wave heights, H_i, the stillwater elevation, S*, a wave period, T_s, and beach slope, m. For Westerly, wave heights range from 5 feet up to the significant wave height of 30 feet; the wave period equals 14 seconds.

These concepts and equations were used to compute wave envelope elevations associated with the 100-year storm surge. Accurate topographic, land-use, and land cover data are required for the coastal analyses. Maps of the study area, at a scale of 1:4,800 with a contour interval of 5 feet were used for the topographic data (Reference 16). The land-use and land cover data were obtained by field surveys.

Wave heights and wave runup were computed along transects which were located perpendicular to the average mean shoreline. The transects were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, the transects were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects. Figure 3, "Transect Location Map," illustrates the location of the transects for the community.

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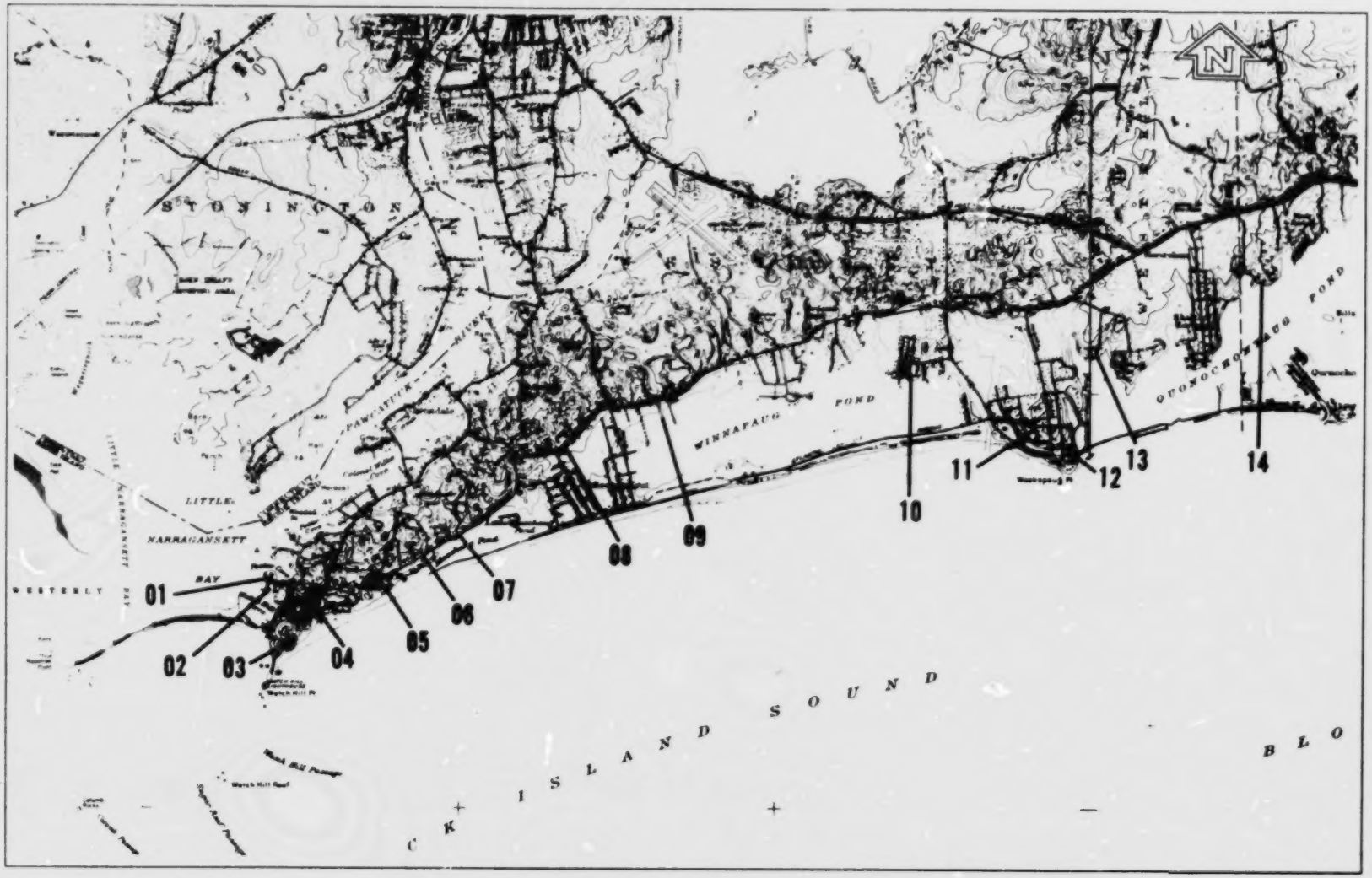

FIGURE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, R.I.

(WASHINGTON CO.)

APPROXIMATE SCALE

1 0 1 2 3 MILES

TRANSECT LOCATION MAP

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Along each transect, wave envelope elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. Between transects, elevations were interpolated using the topographic maps, land-use and land cover data, and engineering judgment to determine the areal extent of flooding. The results of the calculations are accurate until local topography, vegetation, or cultural development within the community undergo any major changes. Selected beach transects with stillwater elevations for the 10- and 100-year recurrence intervals and wave envelope profiles for the 100-year recurrence interval are shown on the Coastal Profiles (Exhibit 2).

An area of shallow flooding has been determined for the lee side of the dunes along Block Island Sound. In this area, the wave runup elevation exceeded the dune crest elevation. The difference between the runup elevation and the dune crest was used to determine the depth of shallow flooding behind the dune (Reference 20).

Areas studied by approximate methods were reviewed using information from community officials, residents, and the most recent FEMA criteria. These criteria consisted of surface area of lakes and ponds, contributing drainage area, depth of flow, and width of flood plains.

All elevations used in this study are referenced to the National Geodetic Vertical Datum of 1929 (NGVD). Elevation reference marks used are shown on the maps.

4.0 FLOOD PLAIN MANAGEMENT APPLICATIONS

The National Flood Insurance Program encourages State and local governments to adopt sound flood plain management programs. Therefore, each Flood Insurance Study produces maps designed to assist communities in developing flood plain management measures.

4.1 Flood Boundaries

To provide a national standard without regional discrimination, the 1 percent annual chance (100-year) flood has been adopted by FEMA as the base flood for flood plain management purposes. The 0.2 percent annual chance (500-year) flood is employed to indicate additional areas of flood risk in the community. For the riverine streams, the 100- and 500-year flood plain boundaries have been delineated using topographic maps (Reference 16).

For tidal areas without wave action, the 100-year and 500-year boundaries were delineated using the topographic maps referenced above (Reference 16). For the tidal areas with wave action, the flood boundaries were

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delineated using the elevations determined at each transect; between transects, the boundaries were interpolated using engineering judgment, land-cover data, and the topographic maps referenced above. The 100-year flood plain was divided into whole-foot elevation zones based on the average wave envelope elevation in that zone. Where the map scale did not permit these zones to be delineated at one foot intervals, larger increments were used.

For the areas studied by approximate methods, the boundary of the 100-year flood was delineated using USGS topographic maps (Reference 21).

The 100- and 500-year flood plain boundaries are shown on the Flood Boundary and Floodway Map (Exhibit 3). In cases where the 100- and 500-year flood plain boundaries are close together, only the 100-year flood plain boundary has been shown. Small areas within the flood plain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

4.2 Floodways

Encroachment on flood plains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of flood plain management involves balancing the economic gain from flood plain development against the resulting increase in flood hazard. For purposes of the National Flood Insurance Program, a floodway is used as a tool to assist local communities in this aspect of flood plain management. Under this concept, the area of the 100-year flood plain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent flood plain areas, that must be kept free of encroachment so that the 100-year flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this study were computed on the basis of equal conveyance reduction from each side of the flood plain. The results of these computations are tabulated at selected cross sections for each stream segment for which a floodway is computed (Table 3).

As shown on the Flood Boundary and Floodway Map (Exhibit 2), the floodway boundaries were computed at cross sections. Between cross sections, the boundaries were interpolated. In cases where the floodway and 100-year flood plain boundaries are either close together or collinear, only the floodway boundary has been shown. Portions of the floodway widths of the Pawcatuck River extend beyond the corporate limits.

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FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
					(FEET NGVD)			
Pawcatuck River								
A	31,500	120/65	801	7.1	12.3	12.3	12.3	0.0
B	32,840	120/60	862	6.6	14.4	14.4	14.5	0.1
C	34,250	159/74	1,113	5.1	15.8	15.8	16.4	0.6
D	35,670	120/60	892	6.4	16.9	16.9	17.8	0.9
E	37,060	495/445	2,363	2.4	19.1	19.1	19.8	0.7
F	37,675	201/136	2,054	2.8	23.1	23.1	23.2	0.1
G	40,492	109/59	1,090	4.8	23.9	23.9	24.1	0.2
H	45,166	146/70	1,475	3.5	25.9	25.9	26.1	0.2
I	51,116	111/60	1,210	4.3	27.4	27.4	27.9	0.5
J	52,728	110/60	1,383	3.8	27.5	27.5	28.5	1.0
K	53,400	105/50	1,190	3.6	27.5	27.5	28.5	1.0
L	54,100	245/145	2,540	1.7	27.8	27.8	28.8	1.0
M	54,350	100/60	1,300	3.3	32.2	32.2	32.2	0.0
N	54,450	150/120	1,880	2.3	32.9	32.9	32.9	0.0
O	55,300	150/60	2,040	2.1	33.0	33.0	33.0	0.0
P	56,800	150/120	2,090	2.0	33.1	33.1	33.1	0.0
Q	58,000	150/90	2,000	2.1	33.2	33.2	33.3	0.1
R	59,000	150/50	2,210	2.0	33.3	33.3	33.4	0.1
S	60,400	150/60	1,870	2.3	33.4	33.4	33.5	0.1
T	61,400	150/50	1,910	2.3	33.5	33.5	33.7	0.2
U	61,700	65/35	620	6.9	33.5	33.5	33.7	0.2
V	61,820	90/20	1,260	3.4	34.3	34.3	34.3	0.0
W	68,400	229/115	2,338	1.8	35.0	35.0	35.2	0.2

[1]Feet above confluence with Little Narragansett Bay

[2]Width/width within corporate limits

TABLE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

FLOODWAY DATA

PAWCATUCK RIVER

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
					(FEET NGVD)			
Pawcatuck River (continued)								
X	78,300[1]	95/45[3]	1,102	3.9	35.8	35.8	36.3	0.5
Y	88,800[1]	190/95[3]	2,135	1.8	36.9	36.9	37.7	0.8
Z	88,905[1]	170/75[3]	1,742	2.2	38.0	38.0	38.2	0.2
AA	91,550[1]	144/55[3]	1,380	2.8	38.6	38.6	38.8	0.2
Mastuxet Brook								
A	150[2]	53	44	5.2	11.2	6.1[4]	6.1	0.0
B	300[2]	88	590	0.4	12.8	12.8	12.8	0.0
C	1,250[2]	45	104	2.2	12.8	12.8	12.8	0.0
D	2,700[2]	28	42	5.5	33.9	33.9	34.2	0.3
E	2,819[2]	20	59	4.0	35.4	35.4	35.5	0.1
F	5,459[2]	80	144	1.6	40.8	40.8	41.8	1.0

[1]Feet above confluence with Little Narragansett Bay

[2]Feet above confluence with Mastuxet Cove

[3]Width/width within corporate limits

[4]Elevation computed without consideration of backwater from Little Narragansett Bay

TABLE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

FLOODWAY DATA

PAWCATUCK RIVER – MASTUXET BROOK

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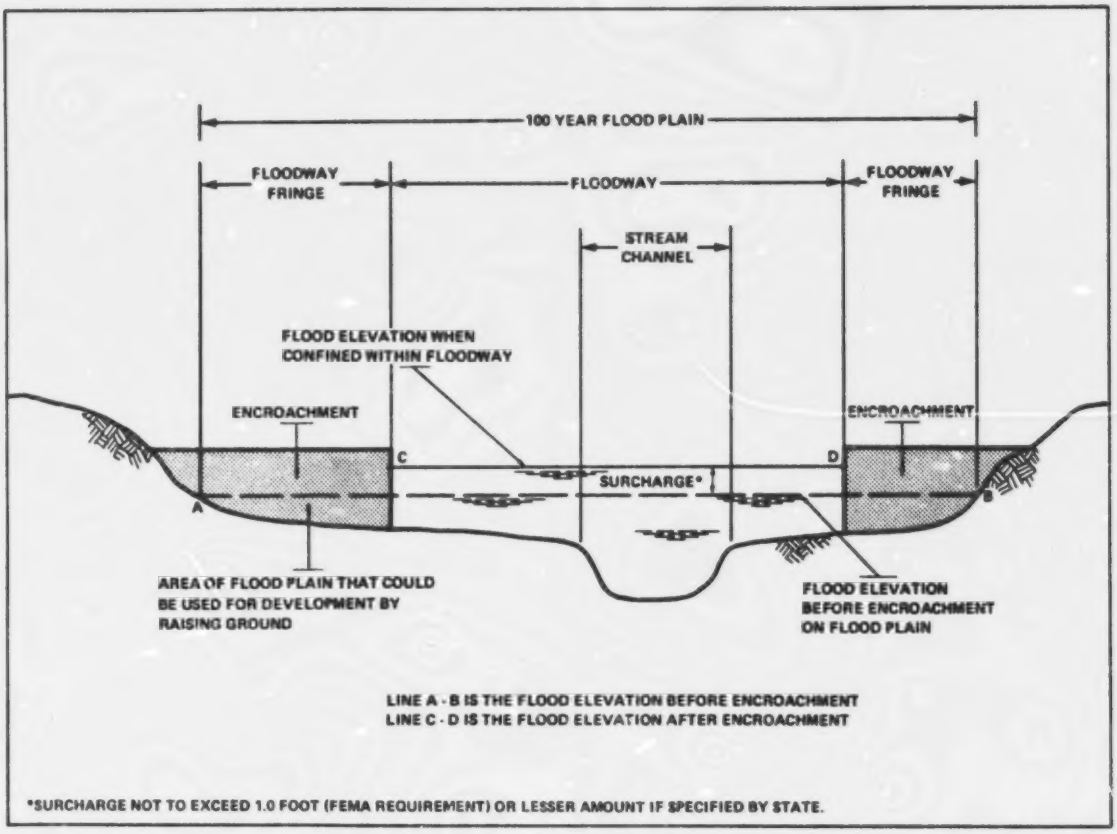
The area between the floodway and 100-year flood plain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the flood plain that could be completely obstructed without increasing the water-surface elevation of the 100-year flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to flood plain development are shown in Figure 4.


100 YEAR FLOOD PLAIN
FLOODWAY FRINGE
FLOODWAY
FLOODWAY FRINGE
STREAM CHANNEL
FLOOD ELEVATION WHEN CONFINED WITHIN FLOODWAY
ENCROACHMENT
ENCROACHMENT
C
D
SURCHARGE*
A
B
AREA OF FLOOD PLAIN THAT COULD BE USED FOR DEVELOPMENT BY RAISING GROUND
FLOOD ELEVATION BEFORE ENCROACHMENT ON FLOOD PLAIN
LINE A - B IS THE FLOOD ELEVATION BEFORE ENCROACHMENT
LINE C - D IS THE FLOOD ELEVATION AFTER ENCROACHMENT
*SURCHARGE NOT TO EXCEED 1.0 FOOT (FEMA REQUIREMENT) OR LESSER AMOUNT IF SPECIFIED BY STATE.

FLOODWAY SCHEMATIC

Figure 4

Near the mouths of streams studied in detail, floodway computations are made without regard to flood elevations on the receiving water body. Therefore, "Without Floodway" elevations presented in Table 3 for certain downstream cross sections of Mastuxet Brook are lower than the regulatory flood elevations in that area, which must take into account the 100-year flooding due to backwater from other sources.

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5.0 INSURANCE APPLICATION

To establish actuarial insurance rates, data from the engineering study must be transformed into flood insurance criteria. This process includes the determination of reaches, Flood Hazard Factors, and flood insurance zone designations for each flooding source studied in detail in the Town of Westerly.

5.1 Reach Determinations

Reaches are defined as sections of flood plain that have relatively the same flood hazard, based on the average weighted difference in water-surface elevations between the 10- and 100-year floods. This difference may not have a variation greater than that indicated in the following tabulation for more than 20 percent of the reach:

Average Difference Between 10- and 100-Year Floods	Variation
Less than 2 feet	0.5 foot
2 to 7 feet	1.0 foot
7.1 to 12 feet	2.0 feet
More than 12 feet	3.0 feet

The locations of the reaches determined for the riverine flooding sources of the Town of Westerly are shown on the Flood Profiles (Exhibit 1) and summarized in Table 4A.

In tidal areas where no wave height analysis was performed, reaches are limited to the distance for which the difference between the 10- and 100-year flood elevations does not vary more than 1.0 foot. Using these criteria, the tidal portion of the Pawcatuck River from a point approximately 4,400 feet above Colonel Willie Cove to the downstream limit of the detailed riverine analysis, qualifies as one reach. This reach is shown in Table 4B.

In areas where wave height and wave runup analyses were performed, reaches were determined for areas of the coastline, represented by a transect or group of transects, which have the same physical characteristics. For each transect the coastal high hazard zone (V zone) may be divided into two reaches to reflect those areas where wave runup is a dominant factor and those areas where wave runup does not dominate and elevations are determined by the wave height analysis. The reaches determined for the Town of Westerly are summarized in Table 4B.

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FLOODING SOURCE	PANEL[1]	ELEVATION DIFFERENCE[2] BETWEEN 1.0% (100-YEAR) FLOOD AND			FHF	ZONE	BASE FLOOD ELEVATION[3] (NGVD)
		10% (10 YR.)	2% (50 YR.)	0.2% (500 YR.)			
Pawcatuck River							
Reach 1	05	-2.0	-0.6	+1.5	020	A4	Varies
Reach 2	05	-1.5	-0.6	+1.5	015	A3	Varies
Reach 3	05,10	-2.0	-0.7	+1.5	020	A4	Varies
Reach 4	10	-2.3	-0.7	+1.6	025	A5	Varies
Reach 5	10	-1.0	-0.3	+1.1	010	A2	Varies
Mastuxet Brook							
Reach 1	15	-0.4	-0.1	+0.3	005	A1	Varies

[1]Flood Insurance Rate Map Panel
[2]Weighted Average
[3]Rounded to the nearest foot - see map

TABLE 4A

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

FLOOD INSURANCE ZONE DATA

PAWCATUCK RIVER – MASTUXET BROOK

TABLE 4B - FLOOD INSURANCE ZONE DATA

Flooding Source	Stillwater Elevation 10-Year	Stillwater Elevation 100-Year	FHF	Zone	Base Flood Elevation (Feet NGVD)*
Block Island Sound	6.9	11.2	065	V13	13-17
			045	A9	11
			055	A11	11-13
	7.0	11.3	065	V13	13-17
			045	V9	14-24
			045	A9	11-24
			055	A11	11-13
	Shallow Flooding - Average Depth 2.0 Feet			A0	--
	Shallow Flooding - Average Depth 2.0 and 3.0 Feet			AH	--
	7.7	11.7	060	V12	14-17
			050	A10	12-14
	7.8	11.9	065	V13	14-18
			040	V8	15-18
			040	A8	15-18
			050	A10	12-14

*Due to map scale limitations, base flood elevations shown on the FIRM represent average elevations for the zones depicted.

5.2 Flood Hazard Factors

The Flood Hazard Factor (FHF) is used to establish relationships between depth and frequency of flooding in any reach. This relationship is then used with depth-damage relationships for various classes of structures to establish actuarial insurance rate tables.

The FHF for a reach is the average weighted difference between the 10- and 100-year flood water-surface elevations rounded to the nearest one-half foot, multiplied by 10, and shown as a three-digit code. For example, if the difference between water-surface elevations of the 10- and 100-year floods is 0.7 foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 015; if the difference is 5.0 feet, the FHF is 050. When the difference between the 10- and 100-year flood water-surface elevations is greater than 10.0 feet, it is rounded to the nearest whole foot.

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5.3 Flood Insurance Zones

Flood insurance zones and zone numbers are assigned based on the type of flood hazard and the FHF, respectively. A unique zone number is associated with each possible FHF, and varies from 1 for a FHF of 005 to a maximum of 30 for a FHF of 200 or greater.

Zone A:	Special Flood Hazard Areas inundated by the 100-year flood, determined by approximate methods; no base flood elevations shown or FHFs determined.
Zone AO:	Special Flood Hazard Areas inundated by types of 100-year shallow flooding where depths are between 1.0 and 3.0 feet; depths are shown but no FHFs are determined.
Zone AH:	Special Flood Hazard Areas inundated by types of 100-year shallow flooding where depths are between 1.0 and 3.0 feet; base flood elevations are shown, but no FHFs are determined.
Zones A1, A2, A3, A4, A5, A8, A9, A10, and A11:	Special Flood Hazard Areas inundated by the 100-year flood; with base flood elevations shown, and zones subdivided according to FHFs.
Zones V8, V9, V12 and V13:	Special Flood Hazard Areas along coasts inundated by the 100-year flood that have additional velocity hazards associated with waves of 3-foot amplitude or greater; with base flood elevations shown, and zones subdivided according to FHFs.
Zone B:	Areas between the Special Flood Hazard Areas and the limits of the 500-year flood; areas that are protected from the 100- or 500-year floods by dike, levee, or other water control structure; areas subject to certain types of 100-year shallow flooding where depths are less than 1.0 foot; and areas subject to 100-year flooding from sources with drainage areas less than 1 square mile. Zone B is not subdivided.
Zone C:	Areas of minimal flooding; not subdivided.

Flood elevation differences, FHFs, flood insurance zones, and base flood elevations for the flooding sources studied in detail in the community are shown in Tables 4A and 4B.

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5.4 Flood Insurance Rate Map Description

The Flood Insurance Rate Map for the Town of Westerly is, for insurance purposes, the principal result of the Flood Insurance Study. This map contains the official delineation of flood insurance zones and base flood elevations. Base flood elevation lines show the locations of the expected whole-foot water-surface elevation of the base (100-year) flood. The base flood elevations and zone numbers are used by insurance agents, in conjunction with structure elevations and characteristics, to assign actuarial insurance rates to structures and contents insured under the National Flood Insurance Program.

6.0 OTHER STUDIES

Stillwater elevations used in this study were interpolated between flood elevations previously determined for FEMA from the study Flood Frequency Analysis of the New London, Connecticut, Tide Gage, and from the study at Narragansett Pier (References 12 and 13). The flood elevations obtained for the shoreline of Westerly are consistent with, but do not match exactly at all locations, tidal flood elvations presented in the COE report Tidal Flood Profiles, New England Coastline (Reference 11). Different methods of analyses used in preparing these studies resulted in the discrepancy between the available tidal flood elevation data for the Town of Westerly. Where hydrologic data developed for use by FEMA were significantly different from elevations presented by the COE, the data developed for FEMA were used for this study.

The Flood Insurance Study for the Town of Stonington, Connectictut, has been published (Reference 8). That study agrees with this study at all locations along the riverine portion of the Pawcatuck River. Flood elevations in the tidal portion of the Pawcatuck River presented in this report supersede the results presented in the Stonington study. The Flood Insurance Study for the Town of Hopkinton, Rhode Island, has also been prepared (Reference 6). The results of that study are consistent with the results of this study.

The Flood Insurance Studies for the Town of North Stonington, Connecticut, and the Town of Charlestown, Rhode Island, are currently being prepared (References 22 and 23). The results of those studies will be in agreement with the results of this study.

Due to its more detailed nature, this Flood Insurance Study supersedes the previous study done for the Town of Westerly (Reference 24).

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7.0 LOCATION OF DATA

Information concerning the pertinent data used in preparation of this study can be obtained by contacting the Natural and Technological Hazards Division, Federal Emergency Management Agency, Regional Director, Region I Office, J. W. McCormack Post Office and Courthouse Building, Room 462, Boston, Massachusetts 02109.

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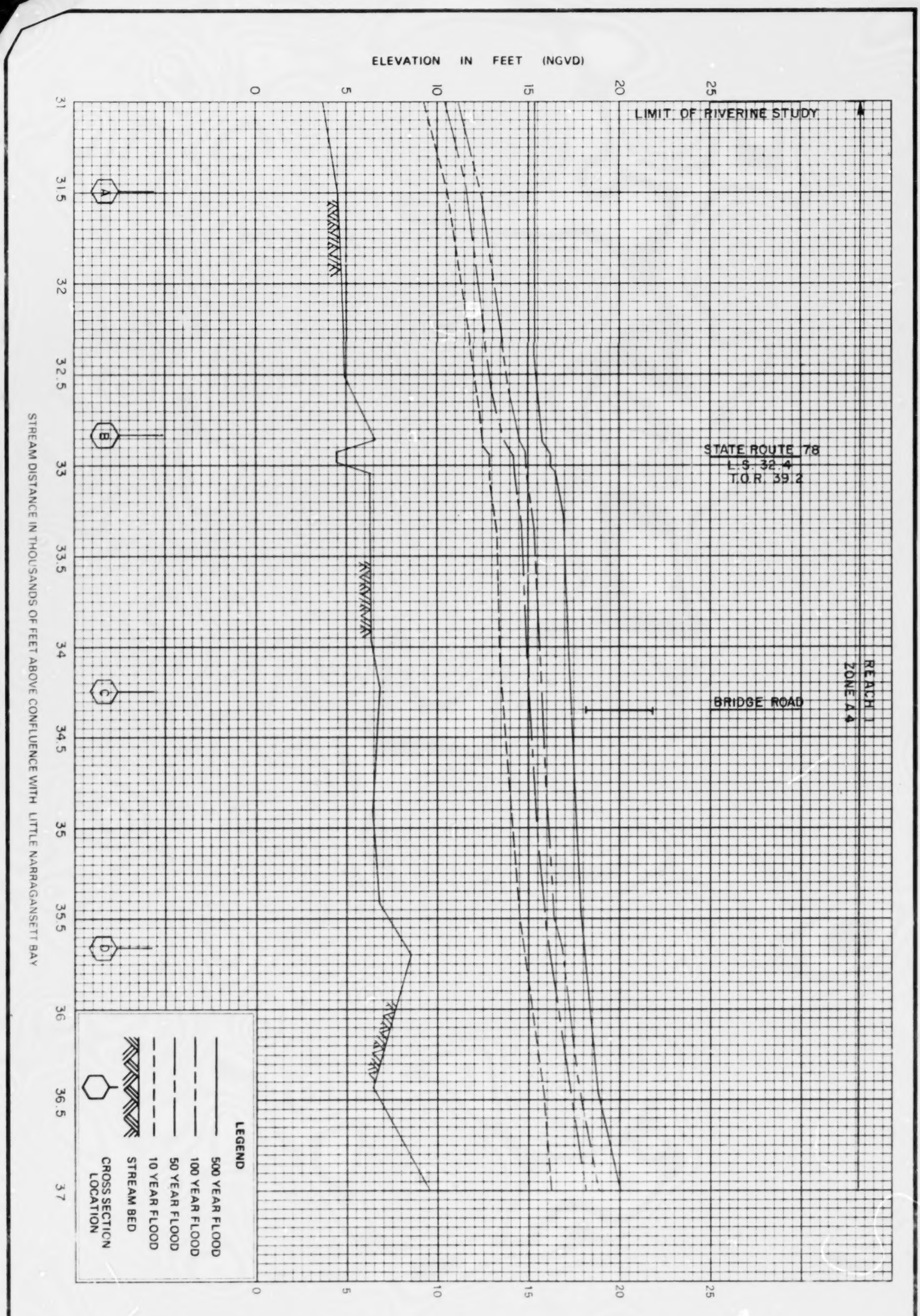

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

FLOOD PROFILES

PAWCATUCK RIVER

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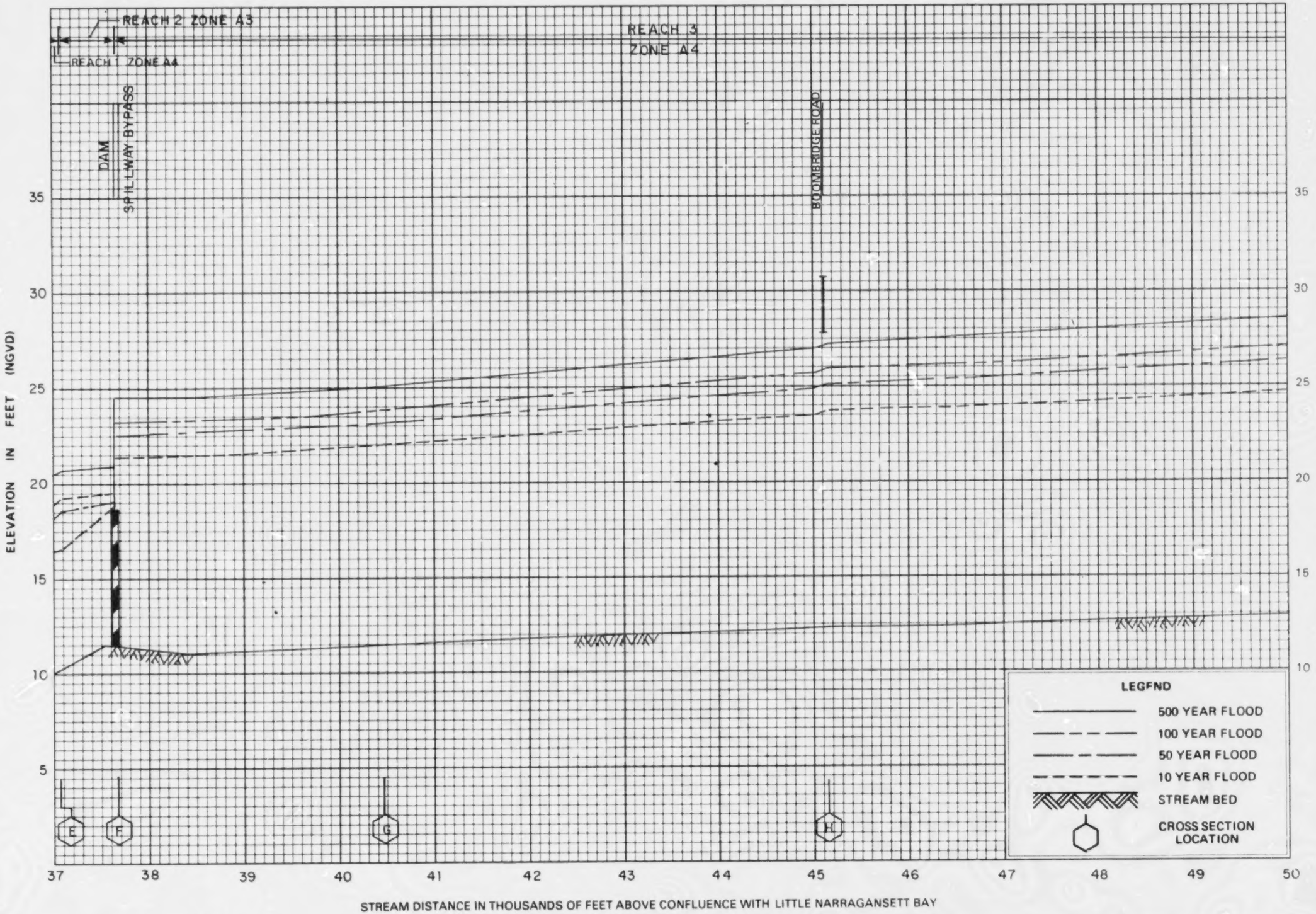

FLOOD PROFILES

PAWCATUCK RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

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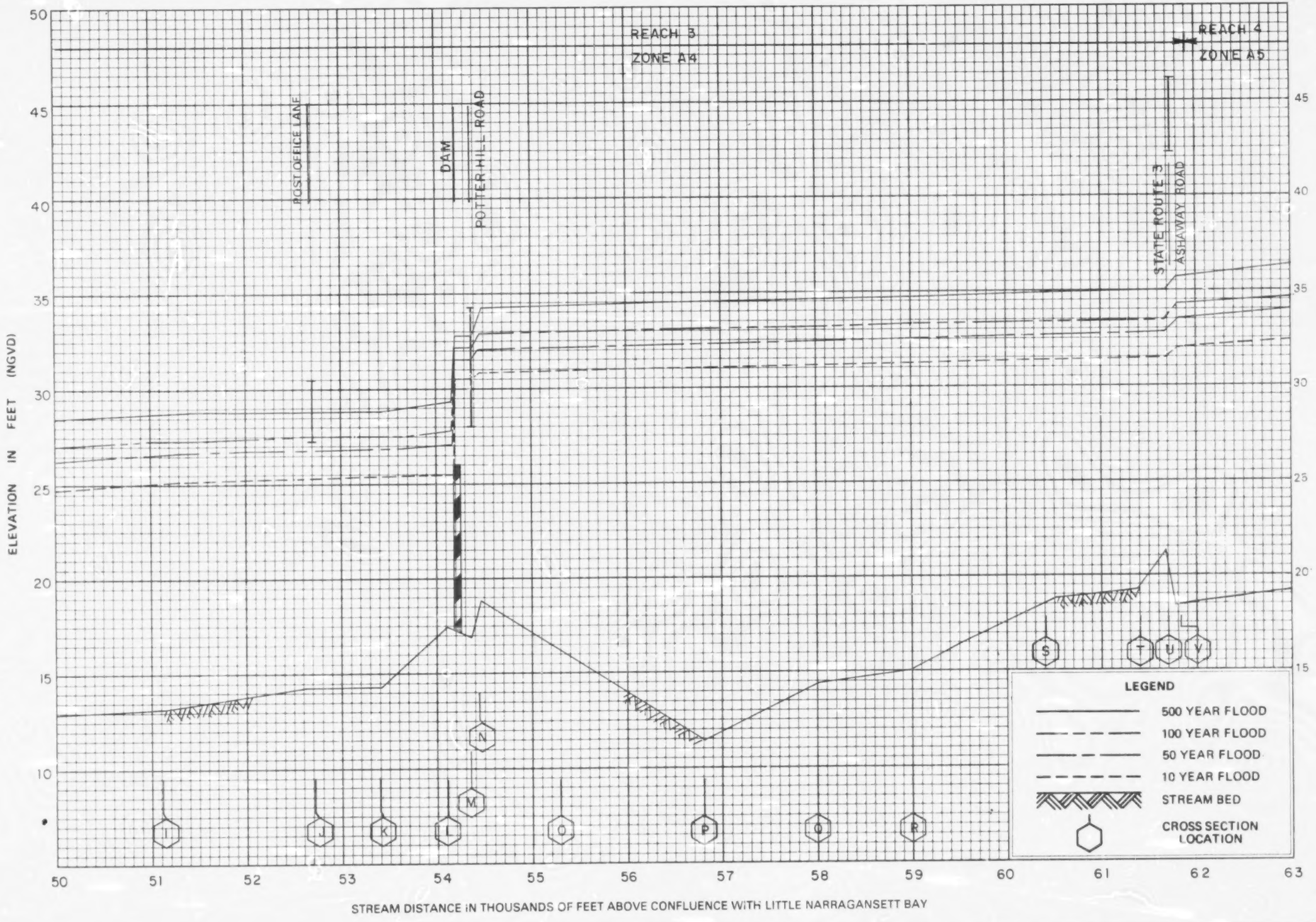

FLOOD PROFILES

PAWCATUCK RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

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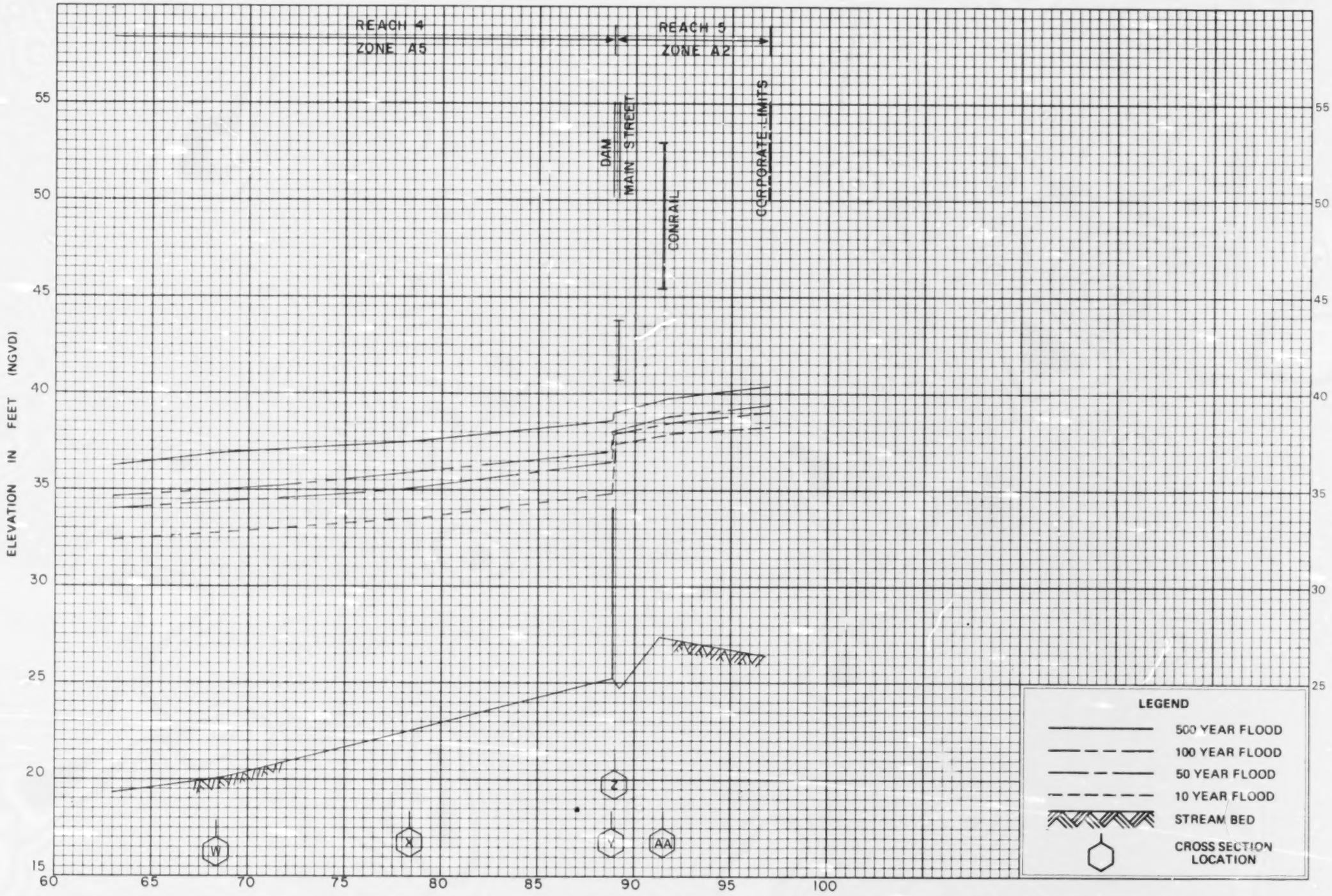

FLOOD PROFILES

PAWCATUCK RIVER

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TOWN OF WESTERLY, RI
(WASHINGTON CO.)

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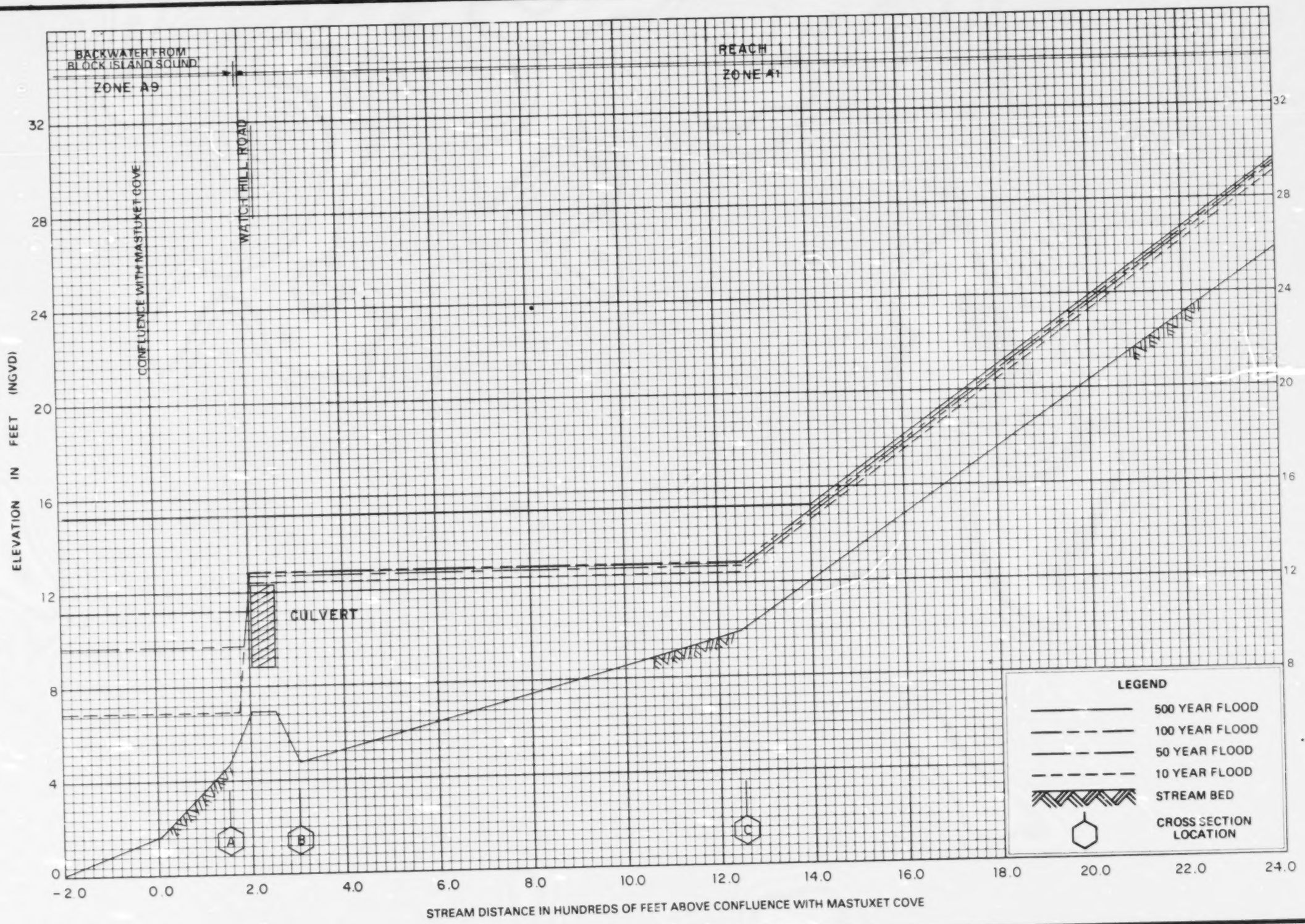

FLOOD PROFILES

MASTUXET BROOK

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TOWN OF WESTERLY, RI
(WASHINGTON CO.)

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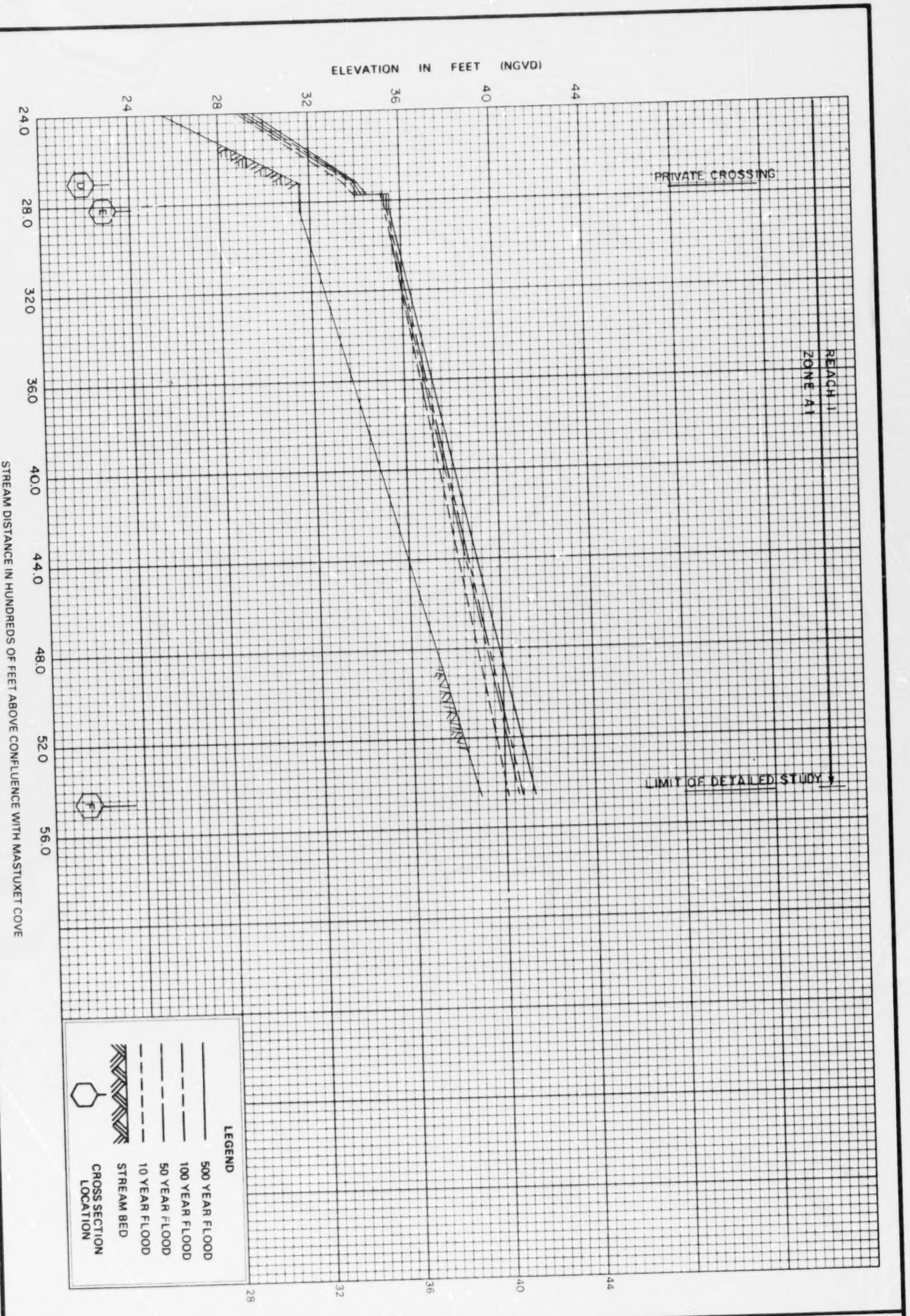

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

FLOOD PROFILES

MASTUXET BROOK

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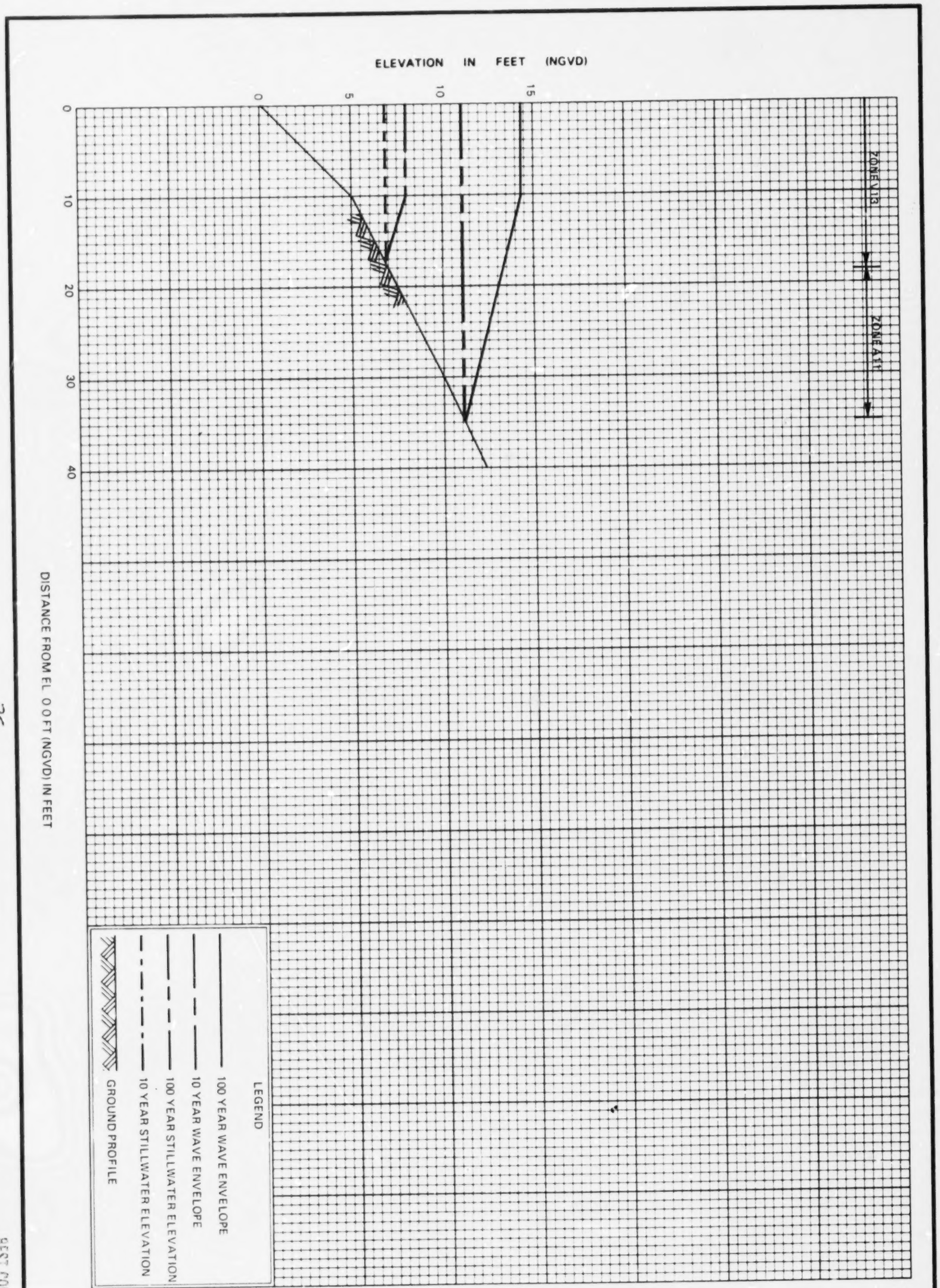

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TOWN OF WESTERLY, RI

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COASTAL PROFILES

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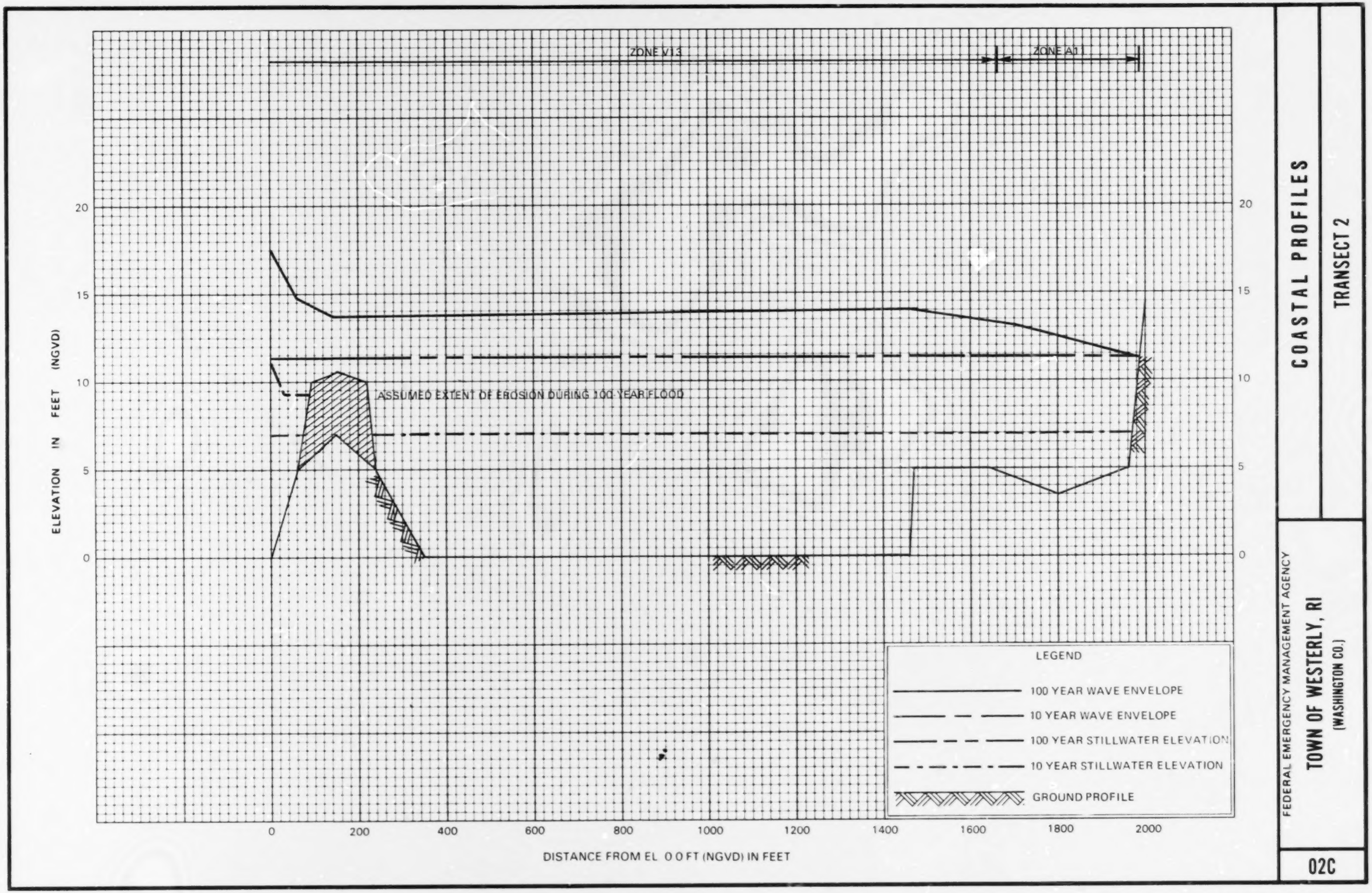

COASTAL PROFILES

TRANSECT 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI

(WASHINGTON CO.)

02C

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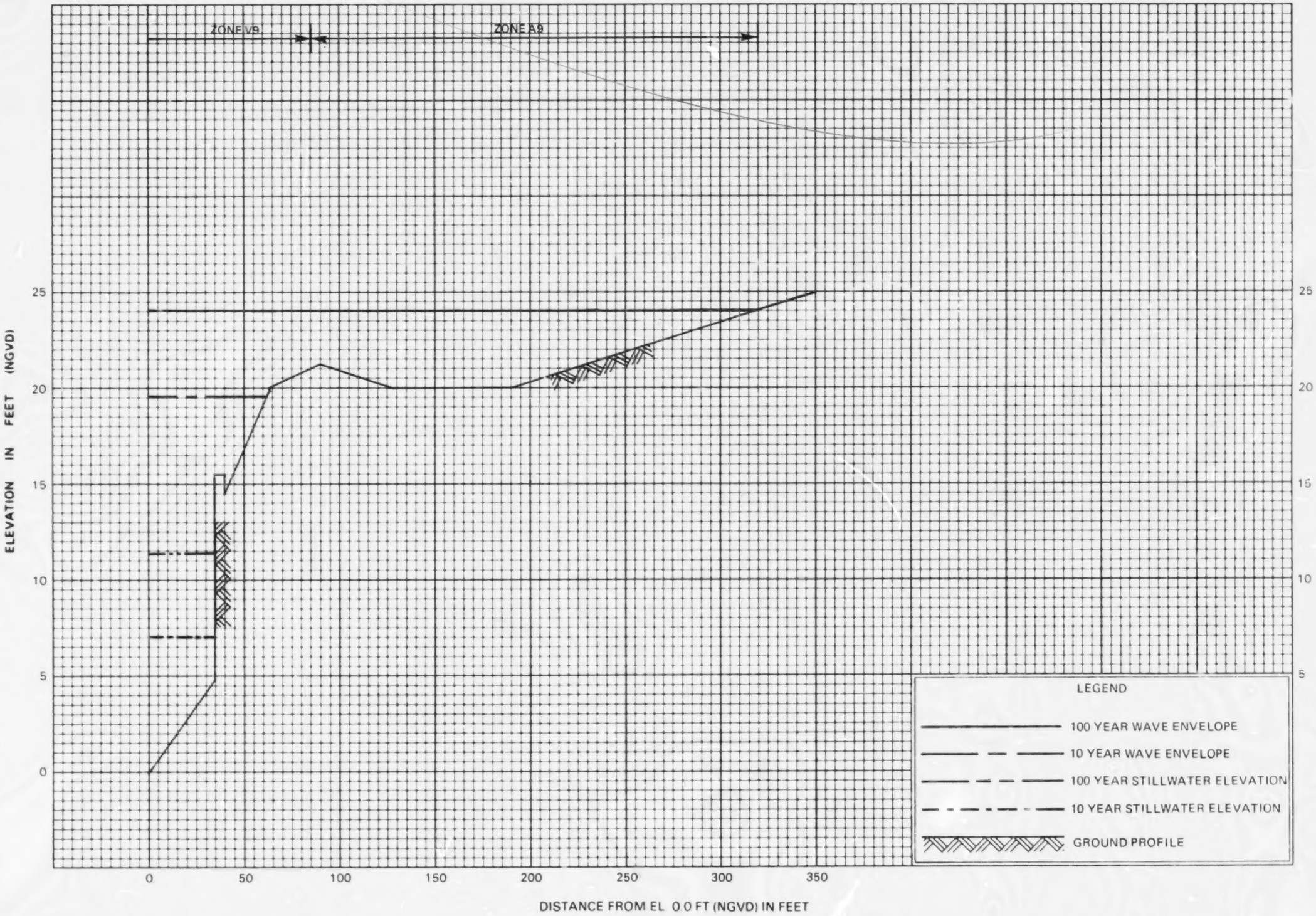

COASTAL PROFILES

TRANSECT 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI

(WASHINGTON CO.)

03C

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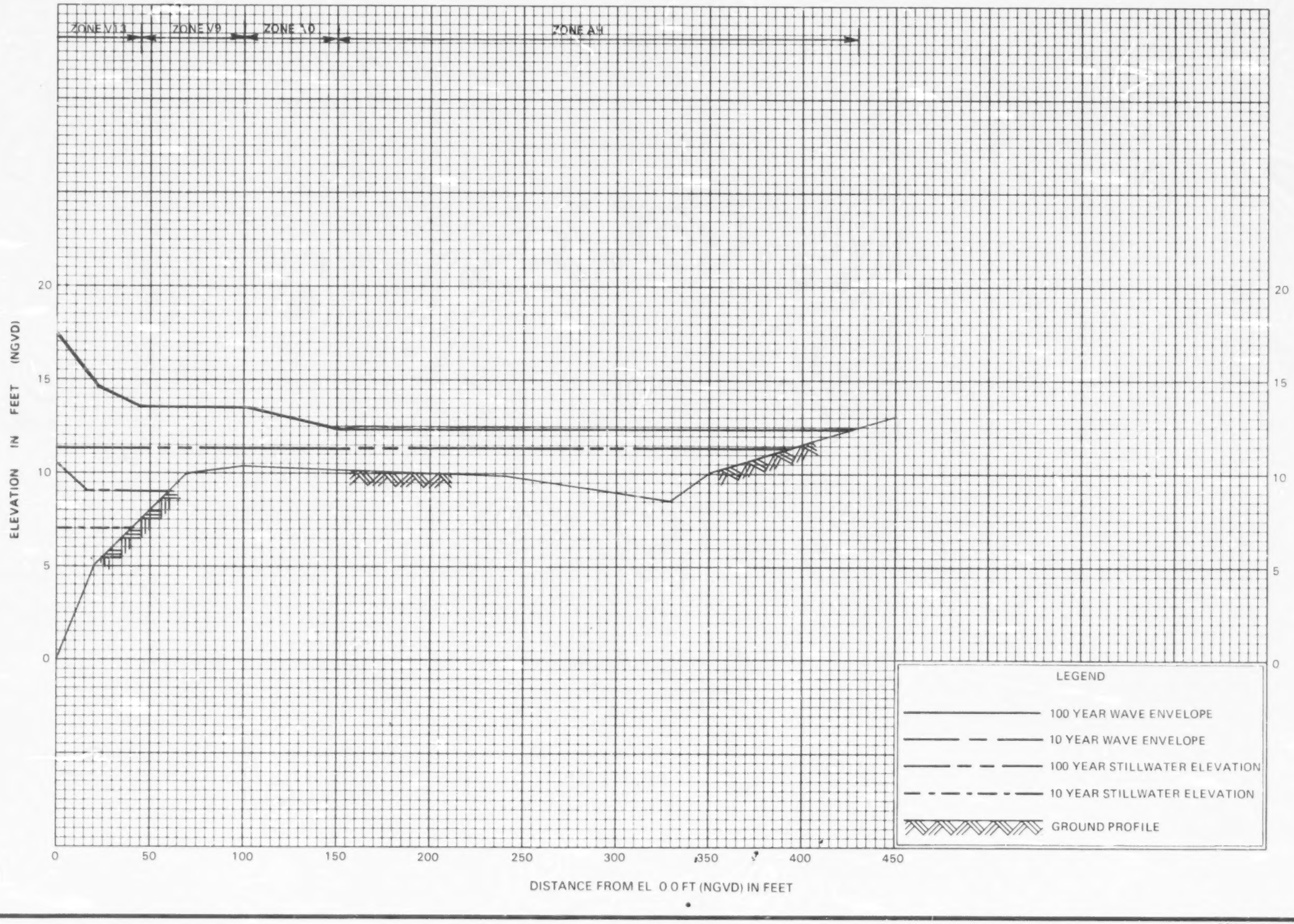

COASTAL PROFILES

TRANSECT 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

04C

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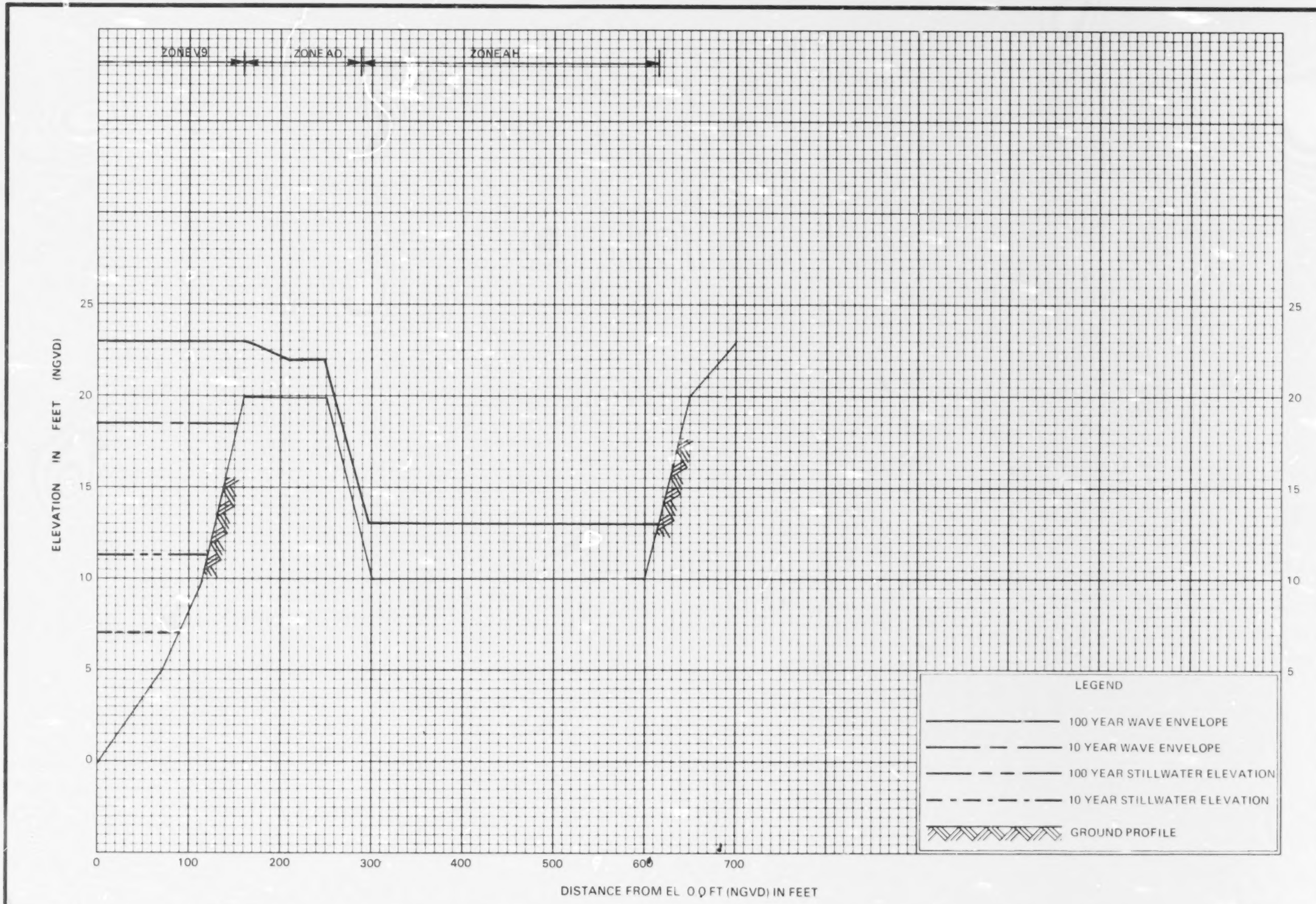

COASTAL PROFILES

TRANSECT 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

05C

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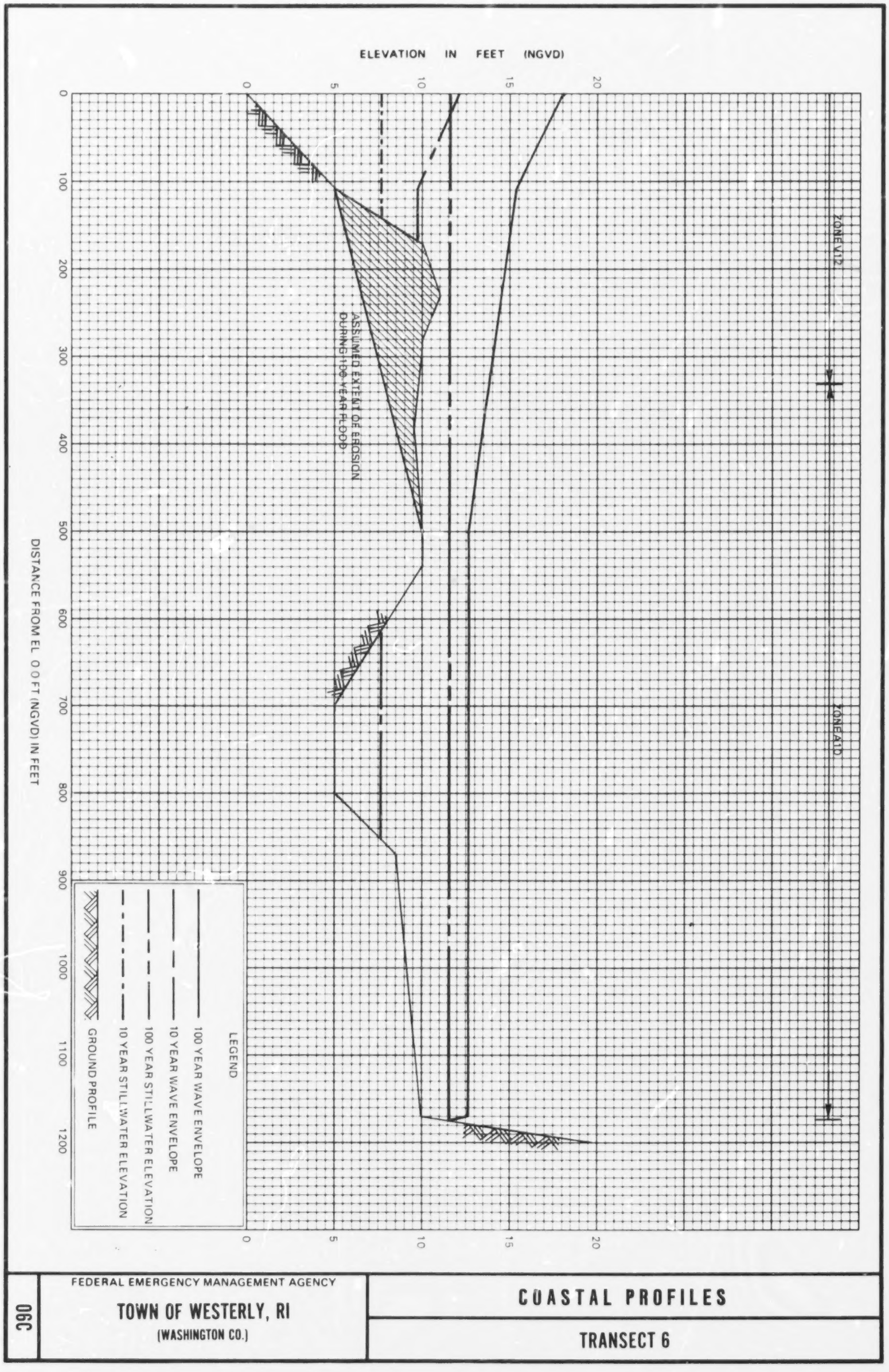

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI

(WASHINGTON CO.)

COASTAL PROFILES

TRANSECT 6

090C

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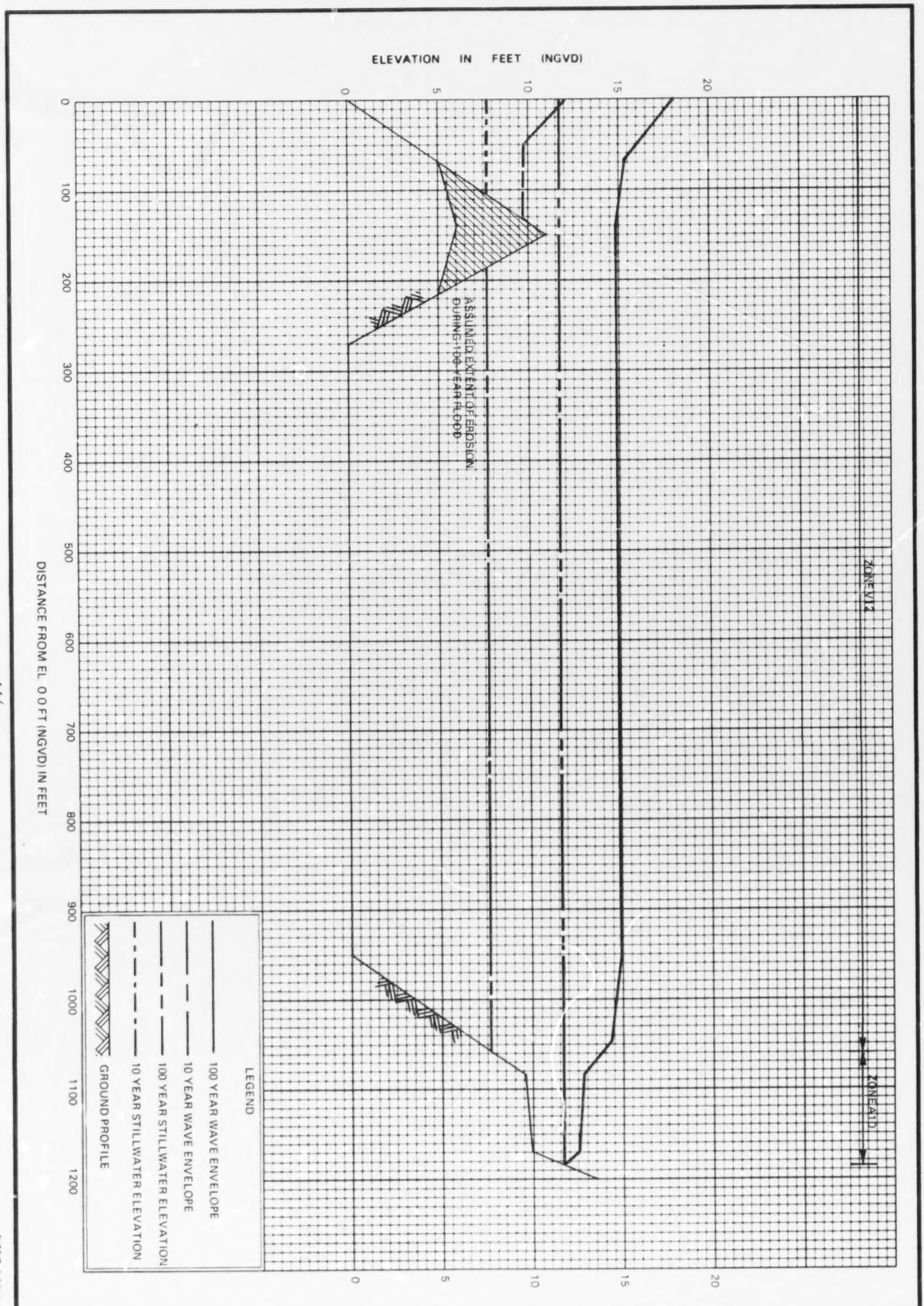

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI

(WASHINGTON CO.)

COASTAL PROFILES

TRANSECT 7

070

41

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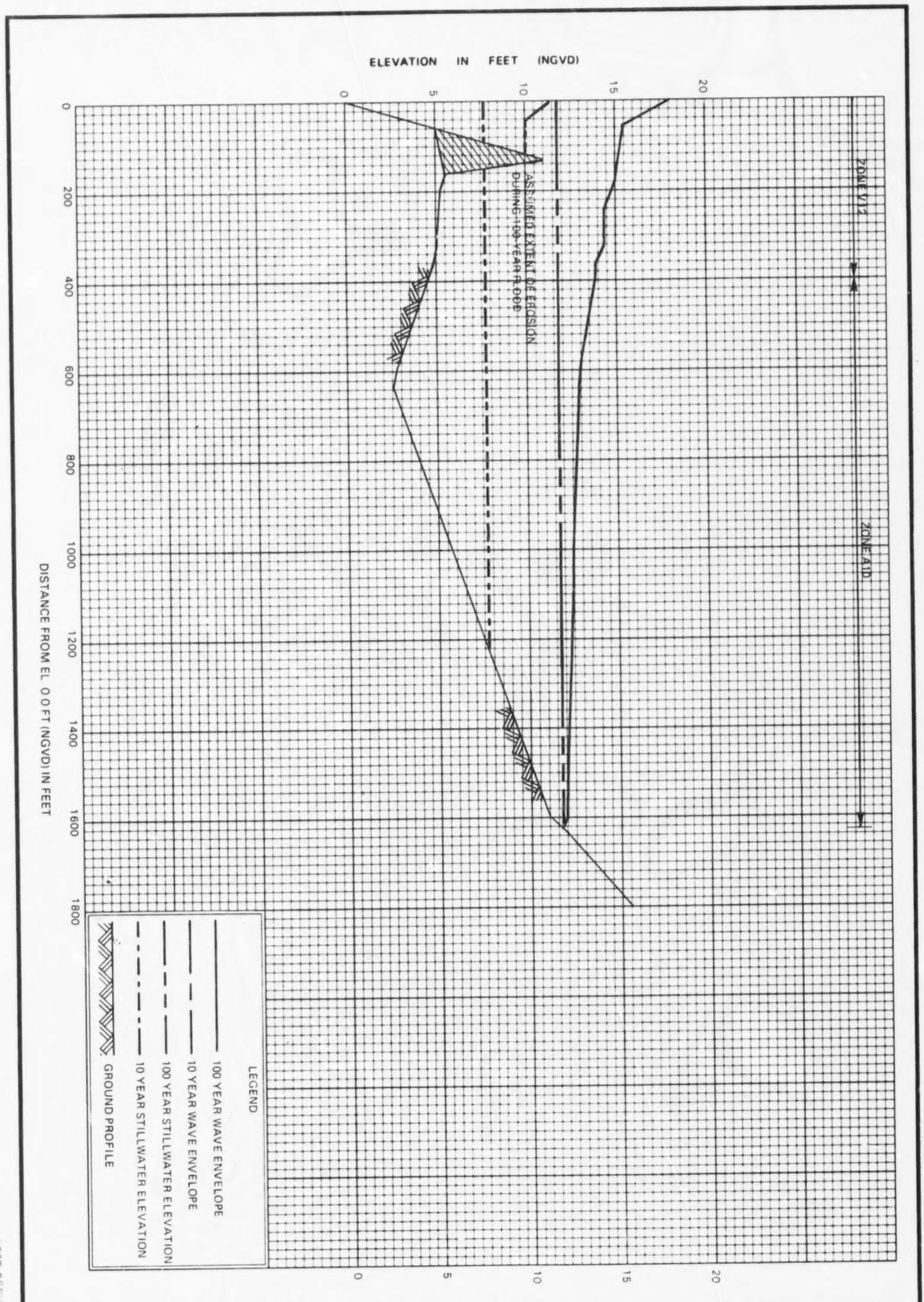

08C	FEDERAL EMERGENCY MANAGEMENT AGENCY **TOWN OF WESTERLY, RI** (WASHINGTON CO.)	**COASTAL PROFILES** **TRANSECT 8**

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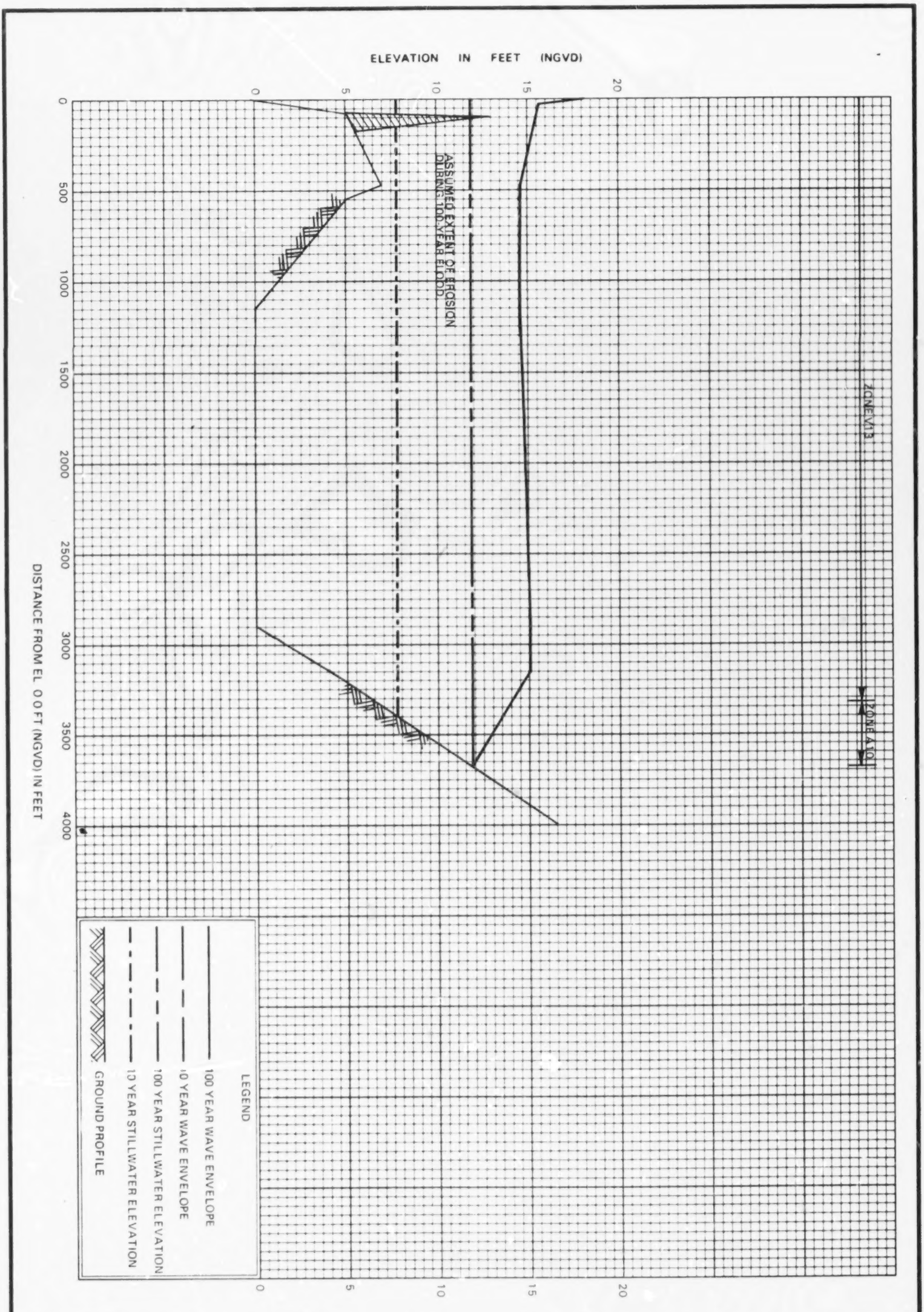

090	FEDERAL EMERGENCY MANAGEMENT AGENCY TOWN OF WESTERLY, RI (WASHINGTON CO.)	COASTAL PROFILES TRANSECT 9

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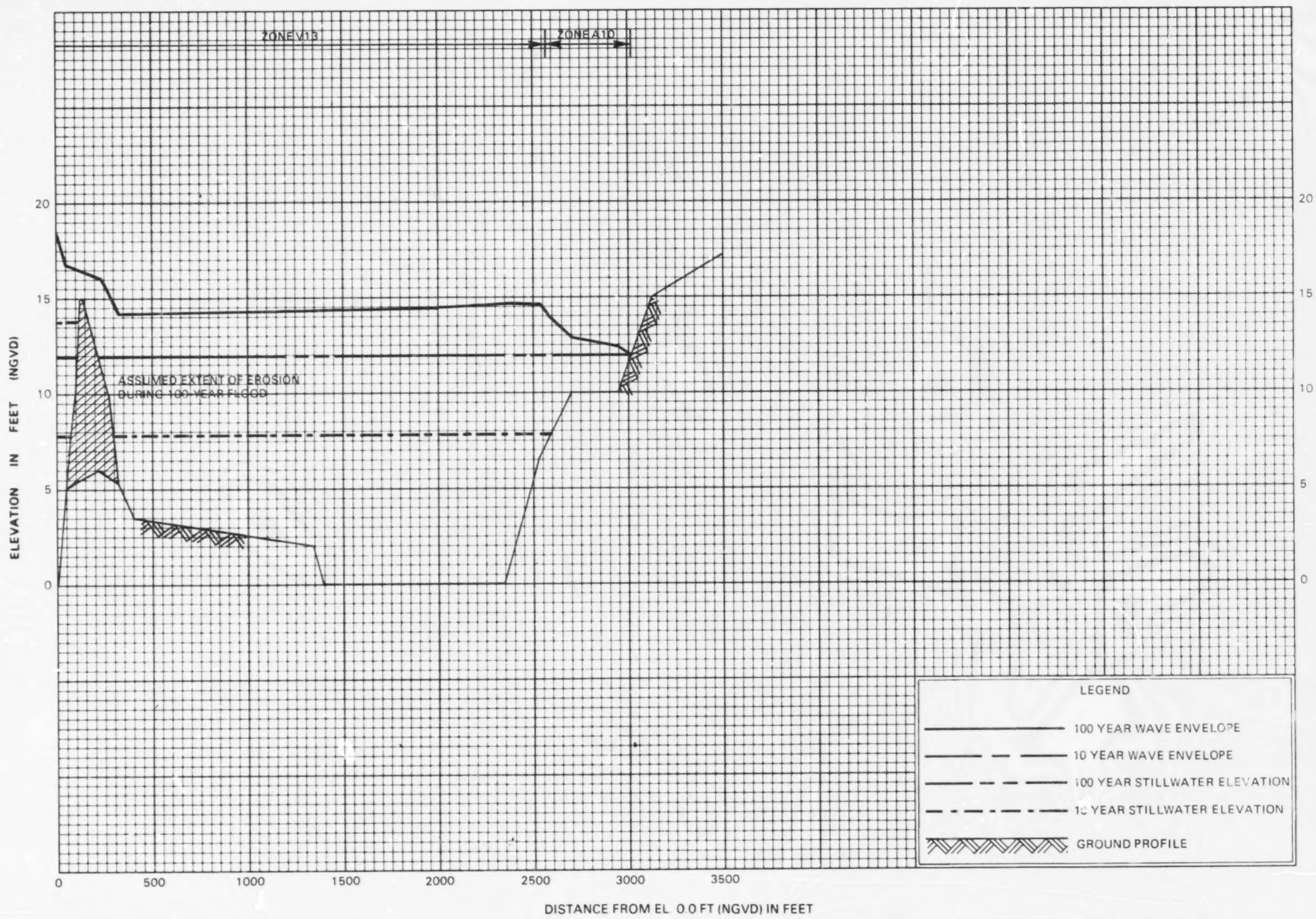

COASTAL PROFILES

TRANSECT 10

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

10C

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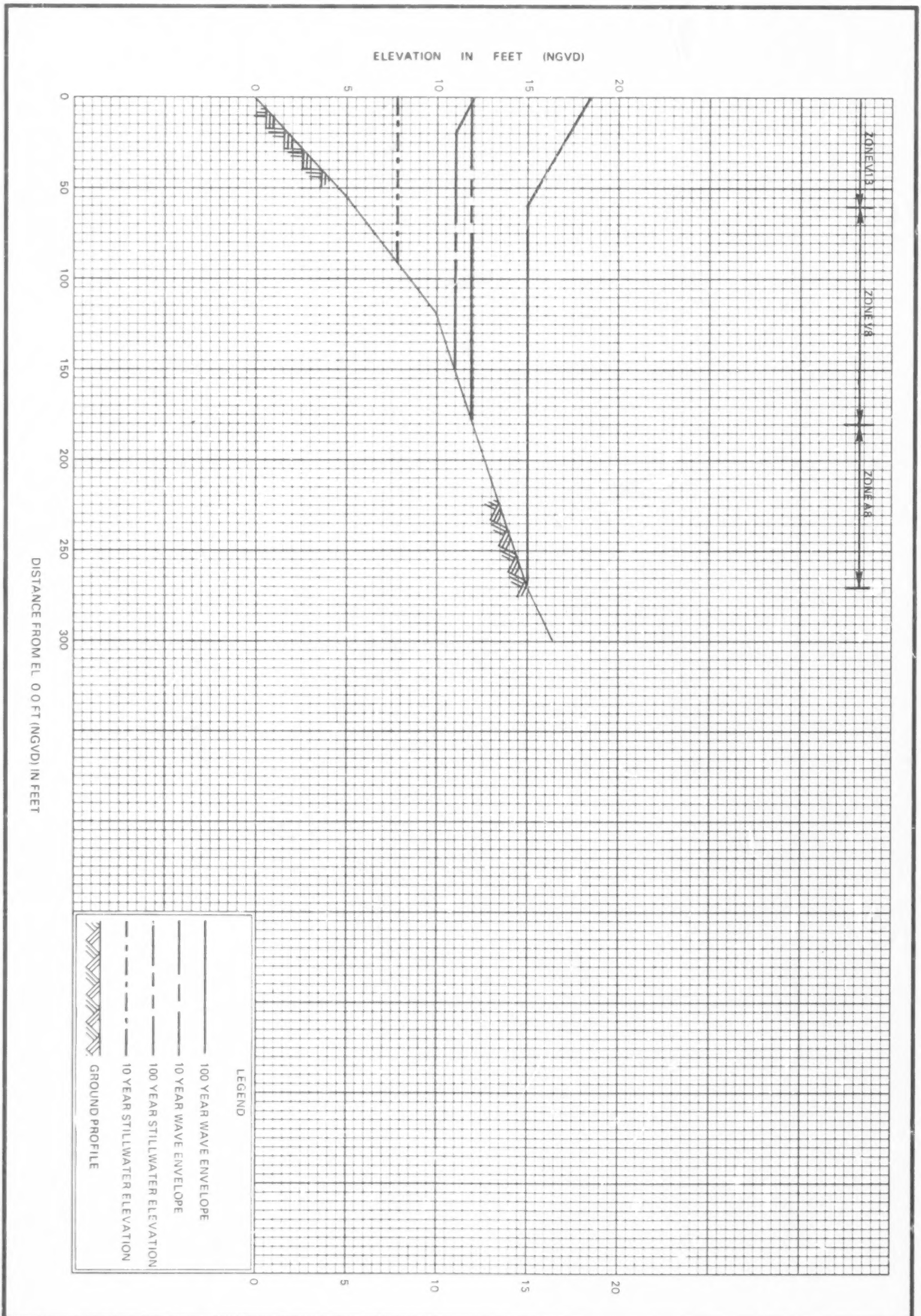

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI

(WASHINGTON CO.)

COASTAL PROFILES

TRANSECT 11

11C

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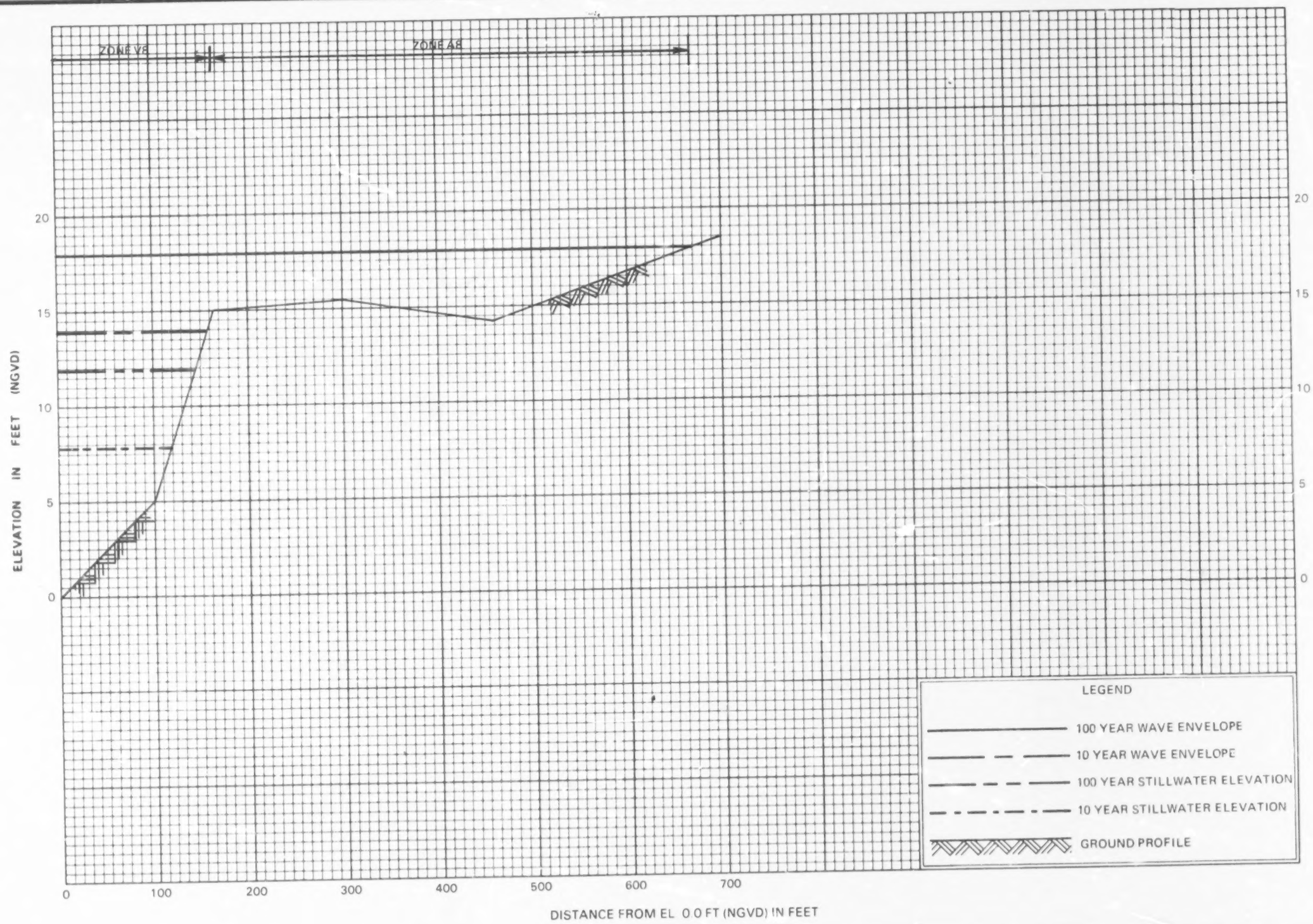

COASTAL PROFILES

TRANSECT 12

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

12C

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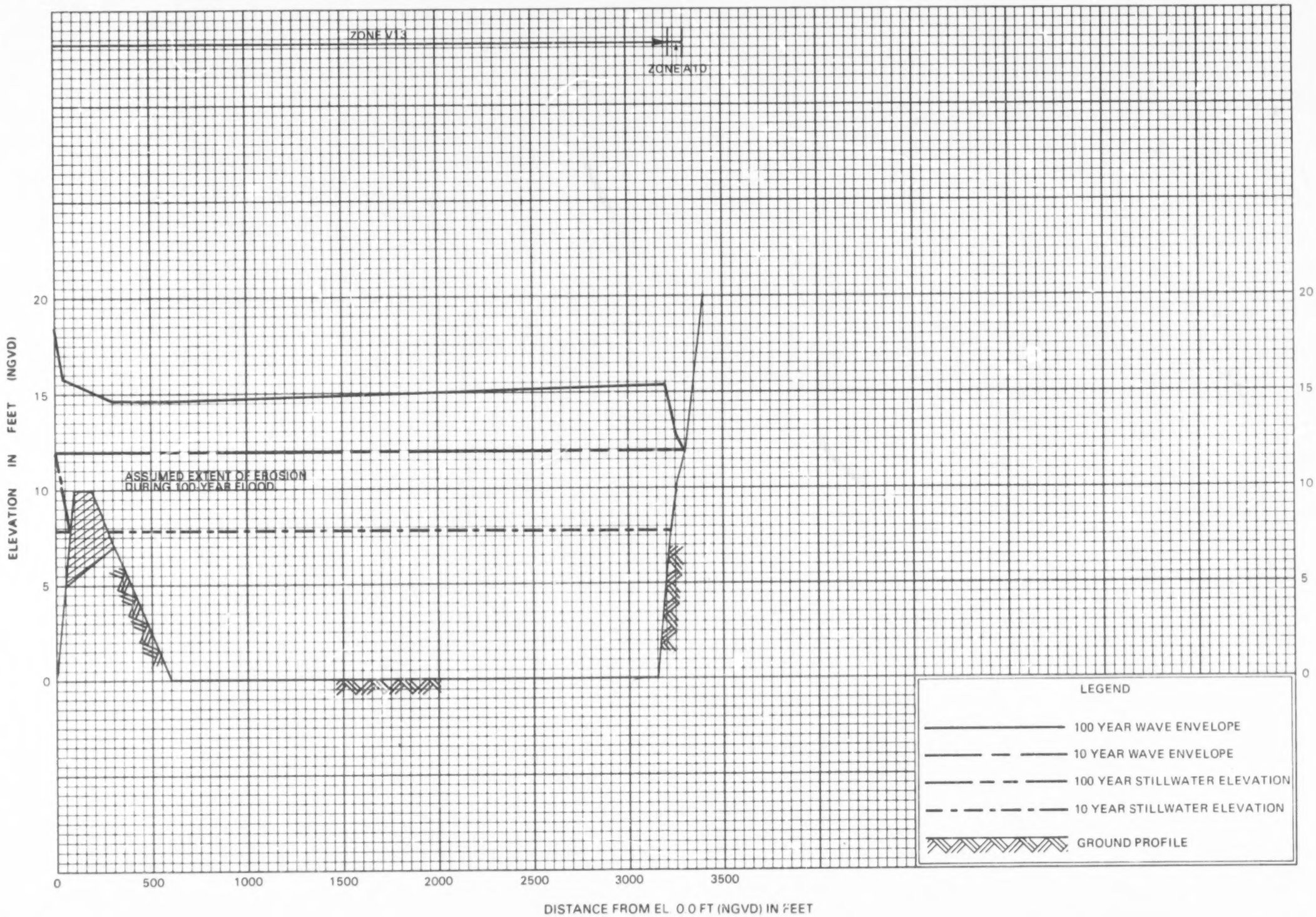

COASTAL PROFILES

TRANSECT 13

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI

(WASHINGTON CO.)

13C

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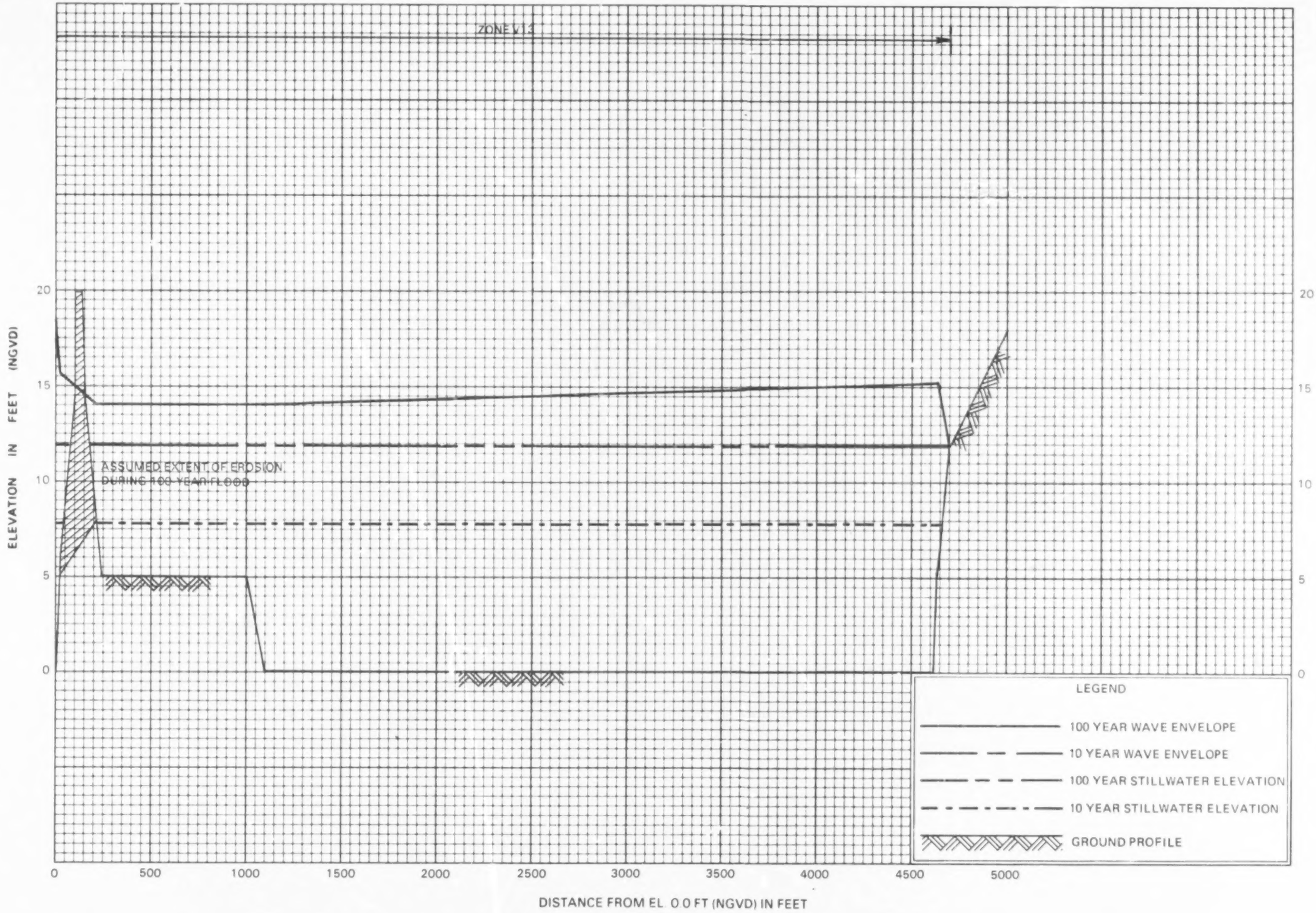

COASTAL PROFILES

TRANSECT 14

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WESTERLY, RI
(WASHINGTON CO.)

14C

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